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A CONTRIBUTION TO THE STUDY OF THE GROWTH OF THE FACE IN CHILDHOOD.

by

Matthew Young M. D.

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The data on which this paper is based are the records of the measurements of numerous facial characters in children up to 14 years of age which were taken by Miss K. C. Smyth for the Dental Committee of the Medical Research Council. The main part of the investigation deals with a series of approximately 1,200 school children ranging in age from 8 to 14 years who were selected as <u>normal</u> in so far that they exhibted a normal or ideal relationship of the upper and lower dental arches, had all the teeth in position and showed no irregularities of individual teeth. As normal, or what may be more aptly described as anatomically correct or <u>ideal</u> occlusion is found in less than 10 per cent of the general child population, the children ultimately selected for measurement were drawn from at least 10 times that number whose dentitions were inspected. In the 1,200 children the sexes were about equally represented and the age distribution was so arranged that about 50 children of each sex belonged to each six-monthly age-group from 8-14 years. Similar measurements were also available in a series of about 100 younger children ranging in age from 2 to 5 years. These measurements were taken in a Children's Home. The 100 children were about equally distributed in the three years and the numbers of each sex at each age were approximately equal. The same series of measurements were also taken in 100 boys at ages 9-10 years who were taken at random from school children of this age.

The characters of which measurements were taken were the following:

1.	Transmeatal axis to nasion	(T.A.to N.)
2.	Transmeatal axis to upper incisor gum margin	(T.A.to U.I.G.M.)
3.	Transmeatal axis to upper incisor incisor margin	(T.A.to U.I.I.M.)
4.	Transmeatal axis to lower incisor gum margin	(T.A.to L.I.G.M.)
5.	Transmeatal axis to mental point	(T.A.to M.P.)
6.	Height of palate	(Pal.Ht.)
7.	Zygomatic breadth of face	(Zyg.B.)
8.	Bigonial breadth of face	(Bigon.B.)
9.	Nasion to sub-nasal point	(N.to S.N.P.)
10.	Nasion to upper incisors	(N.to U.Inc.)
11.	Nasion to occlusal surface of upper first molars	(N.to $\underline{6 \mid 6}$)
12.	Nasion to submental point	(N.to S.M.P.)
13.	Lower incisors to submental point	(L.Incis.to S.M.P.)
14.	Lower molars (occlusal surface) to lower border of the mandible	(L.M.to L.B.M.)
15.	Length of upper dental arch	(L.U.A.)
16.	Length of lower dental arch	(L.L.A.)
17.	External breadth of upper dental arch at first deciduous molar or premolar	(B.at D.or $\underline{4 \mid 4}$
18.	External breadth of upper dental arch at first permanent molar	(B.at $\underline{6 \mid 6}$
19.	External breadth of lower dental arch at first deciduous molar or premolar	(B.at $\overline{4 \mid 4}$
20.	External breadth of lower dental arch at first permanent molar	(B.at $\overline{6 \mid 6}$

For a certain number of the children, the internal measurements of the upper and lower dental arches at the first deciduous molar or premolar and at the first permanent molar were also given as well as the widths of the central and lateral incisors of the upper jaw.

The measurements were given in millimetres in most cases correct to the nearest half millimetre but in the smaller characters correct to decimals of a millimetre. For each child there was also available the exact age in years and months, the full stature in centimetres measured to the nearest half centmetre and the body weight in kilograms.

Most of the terms describing the measurements that were taken do not require any further explanation to indicate clearly the points of contact but it may facilitate an exact appreciation of the nature of some of the characters if the description is somewhat amplified. The term height of the palate is the vertical distance of the palate in the mid-line from a horizontal line at the level of the occlusal or morsal surfaces of the first permanent molar. This was measured with a specially devised instrument. Length of the upper dental arch referred to by Franke as the height of the ~~dental~~ alveolar arch is the distance in the mid-line from the incisor margin to the mid-point of the transverse line joining the distal surfaces of the first permanent molars. The length of the lower arch is the distance between the corresponding points described for the upper. In the children at 2-5 years the measurement is from the incisor margin to the mid-point of the transverse line connecting the distal surfaces of the 2nd milk molars.
The external width of the dental arch is measured anteriorly at the first deciduous molars or first premolars and more posteriorly at the first permanent molars at the widest part at the junction of tooth and gum margin. The internal measurements of the arch are taken from the inside of the corresponding teeth at the same level.

The primary object of the investigation was to establish standards of normality or norms for the different facial characters with the object of facilitating the study of abnormal conditions of the face and jaws but it is obvious that such a wealth of material provides ample means for a study of the growth of the face with special reference to the jaws in childhood and suitable data for determining the interrelationships of the several pairs of characters and changes or variations in these interrelationships with increasing age.

Mean measurements of physical characters where growth is in progress as in children are usually tabulated according to age or age groups though some observers believe, that it might be a better procedure to tabulate the mean values for groups of children graded according to height or for certain height groups. In a preliminary survey of some of the data which were collected for the present investigation it was found that the correlations between some of the characters and full stature seemed to exceed in value those between the corresponding characters and age and the Committee responsible for the collection of the data decided that the mean values of the various measurements should be tabulated for stature groups in preference to age groups. As more detailed examination of the data which ultimately became available, however, showed that the association of many of the characters with age was more intense than with height, it was considered to be advisable to tabulate the mean values for age as well as for full stature. For practical purposes, the correlation between stature and age is so high and between the several characters and age and stature respectively so nearly alike in most instances that it seems to be immaterial on which of the two bases tabulation is made. Both age and height might be expected to show a closer association with the various characters than body weight but, as will be referred to more fully later, it was found rather unexpectedly that the correlation between most of the characters and body weight was appreciably higher than between these variables and either age or stature. Most people are, however, accustomed to think of children in terms of age rather than in terms of stature; the relationship of the characters to age is of more general interest than the association with height and there are no comparable data published by other observers for facial characters graded according to height. For these and other reasons the writer thinks that attention should be concentrated on the classification according to age.

The mean values with their standard errors, the standard deviations or variability of the several facial characters and the number of observations on which each average is based tabulated according to age are shown in Tables 1 and 2 and according to full stature for the separate sexes in Tables 4 and 5. Approximately 50 children of each sex had been measured for each six-monthly group between 8 and 14 years but as some of the data could not be used it was deemed advisable to tabulate the results for yearly age groups which seemed to be sufficiently narrow for the purpose in view and all that were really warranted by the number of observations available. In the complete series of children the full stature varied from 110 to 168.5 cm and five centimetre intervals seemed to form a suitable scale for grouping. Thus the averages were calculated for the stature groups 110-115 cm, 115-120 cm ,,...... 160-165 cm and 165 cm. As in the collection of children for the present investigation there was selection according to age but none in regard to height the tabulation by age groups in Table 1 and 2 is definitely to be preferred to the grading according to stature in Tables 4 and 5. In the grouping according to stature, the numbers of observation are exceedingly small towards the limits of the range and are quite inadequate to give mean values with any claim to be regarded as stable except towards the middle of the scale of frequency. Some standard deviations for relatively small numbers towards the limits of the range have been inserted but it is obvious little significance can be attached to them.

From the results given in the tables graphs have been prepared showing for each sex, the mean values of each character plotted against age and against height, the corresponding graphs for boys and girls appearing in the same diagram. Of this very large number of graphs six are submitted as examples of what is demonstrated.

Although it is generally known that growth of many physical characters does not exhibit a linear relationship with respect to age, or in other words, that the mean values of such a character at successive ages over an extended period of life do not fall approximately on a straight line, it may be otherwise for a relatively short age period such as 8 to 14 years for which data are available in the present investigation where growth is making rapid progress. By comparing the coefficients of correlation ($\underline{r}$) and the correlation ratios ($\underline{\eta}$) for the several characters and both age and height by the test usually applied (Blakeman's criterion of linearity) it is shown that practically all the characters under review, with the exception of L.U.A. and L.L.A., present a linear relationship to both age and height and that the increase in mean value with age or height can be represented quite adequately by straight lines. The regression equations expressing the relationship between each character and age and height respectively have been calculated and the straight lines which are drawn through the series of means of the successive arrays in the diagrams are the lines represented by the equations.

The provision of the mean measurements of the several characters and their standard errors with the standard deviation of the distributions at the different ages and for the different stature groups fulfilled the original purpose of the investigation namely to establish standards or norms for the several characters. We nay now discuss the means by which these may be utilised to facilitate the study of abnormalities of the face and jaws

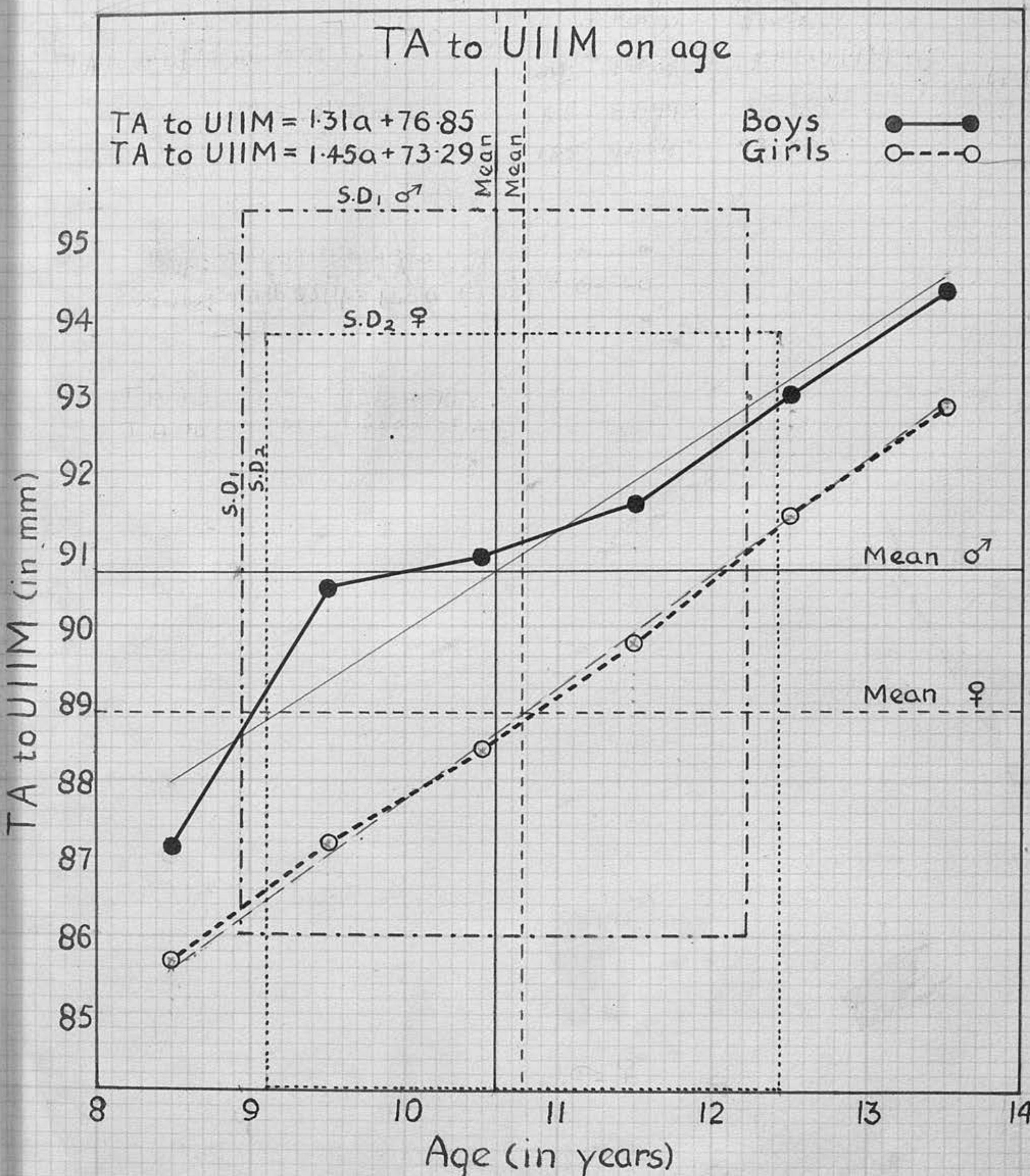
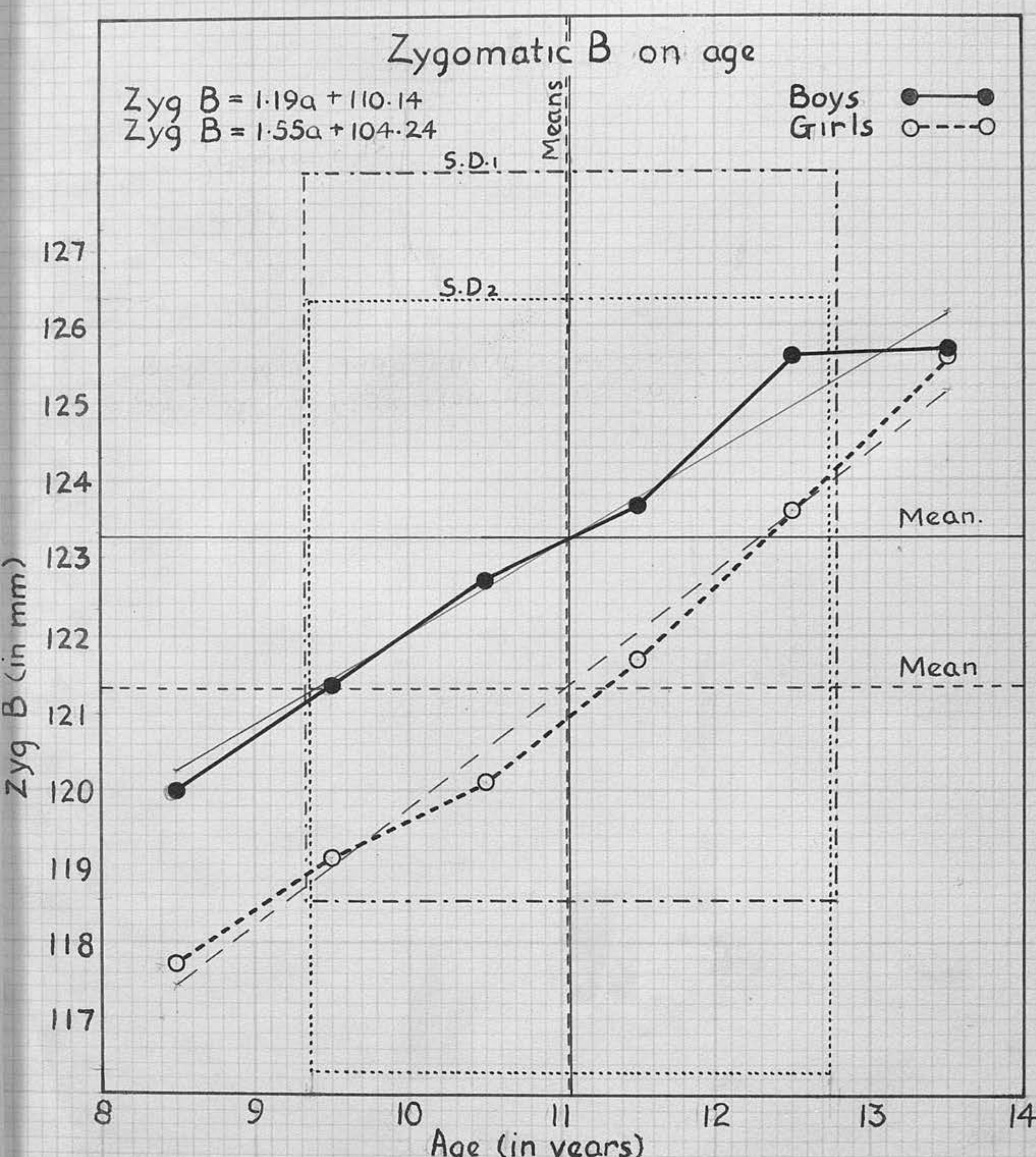

TA to U11M on age
TA to U11M = 1·31a + 76·85
TA to U11M = 1·45a + 73·29
Boys
Girls
S.D₁ ♂
S.D₂ ♀
Mean
Mean
S.D₁
S.D₂
Mean ♂
Mean ♀
95
94
93
92
91
90
89
88
87
86
85
TA to U11M (in mm)
8
9
10
11
12
13
14
Age (in years)

DIAGRAM 1


Zygomatic B on age
Zyg B = 1·19a + 110·14
Zyg B = 1·55a + 104·24
Boys
Girls
Means
S.D.1
S.D2
Mean.
Mean
127
126
125
124
123
122
121
120
119
118
117
Zyg B (in mm)
8
9
10
11
12
13
14
Age (in years)
DIAGRAM 2

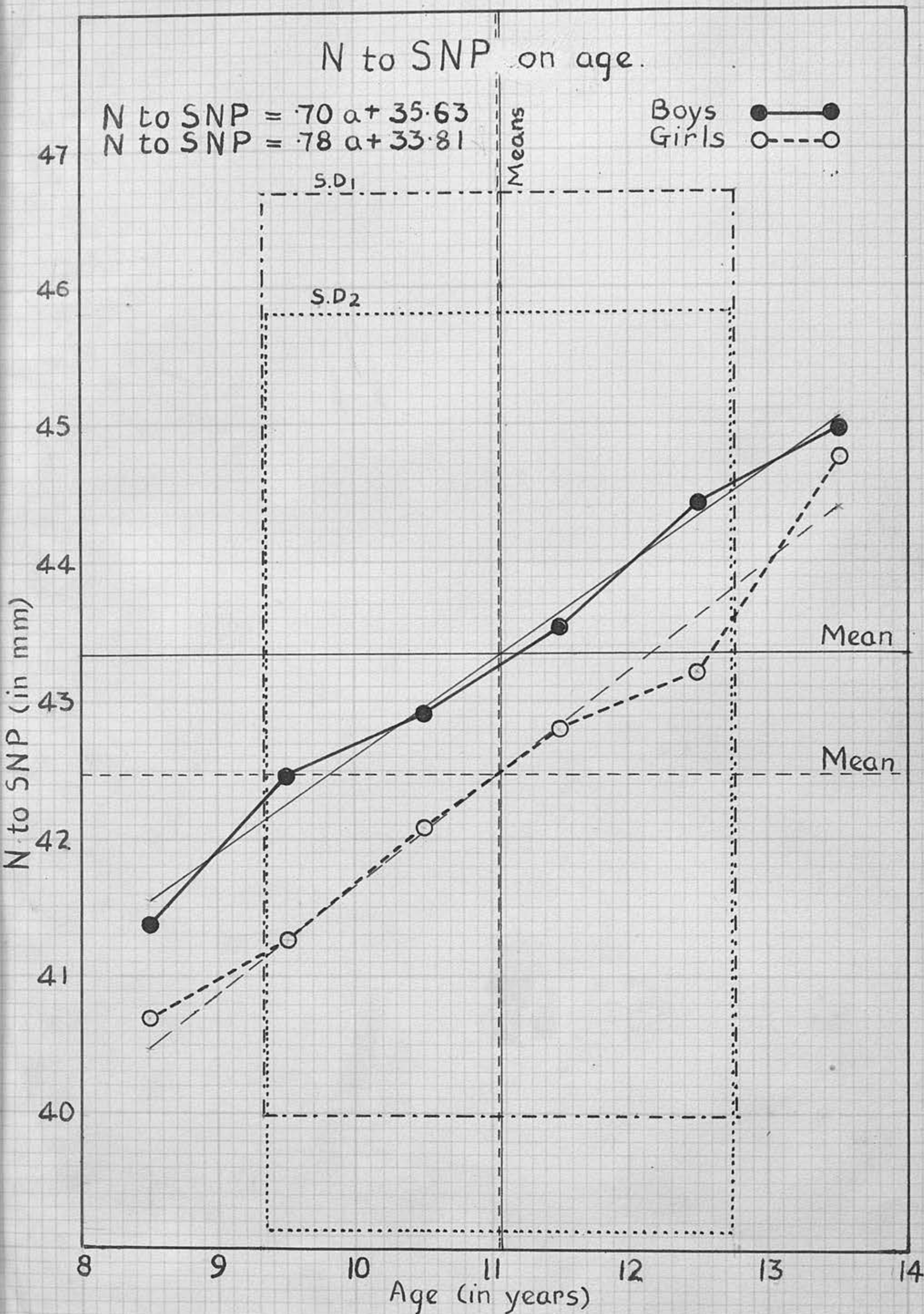

N to SNP on age.
N to SNP = ·70 a + 35·63
N to SNP = ·78 a + 33·81
Boys
Girls
Means
S.D1
S.D2
Mean
Mean
N to SNP (in mm)
47
46
45
44
43
42
41
40
8
9
10
11
12
13
14
Age (in years)

DIAGRAM 3

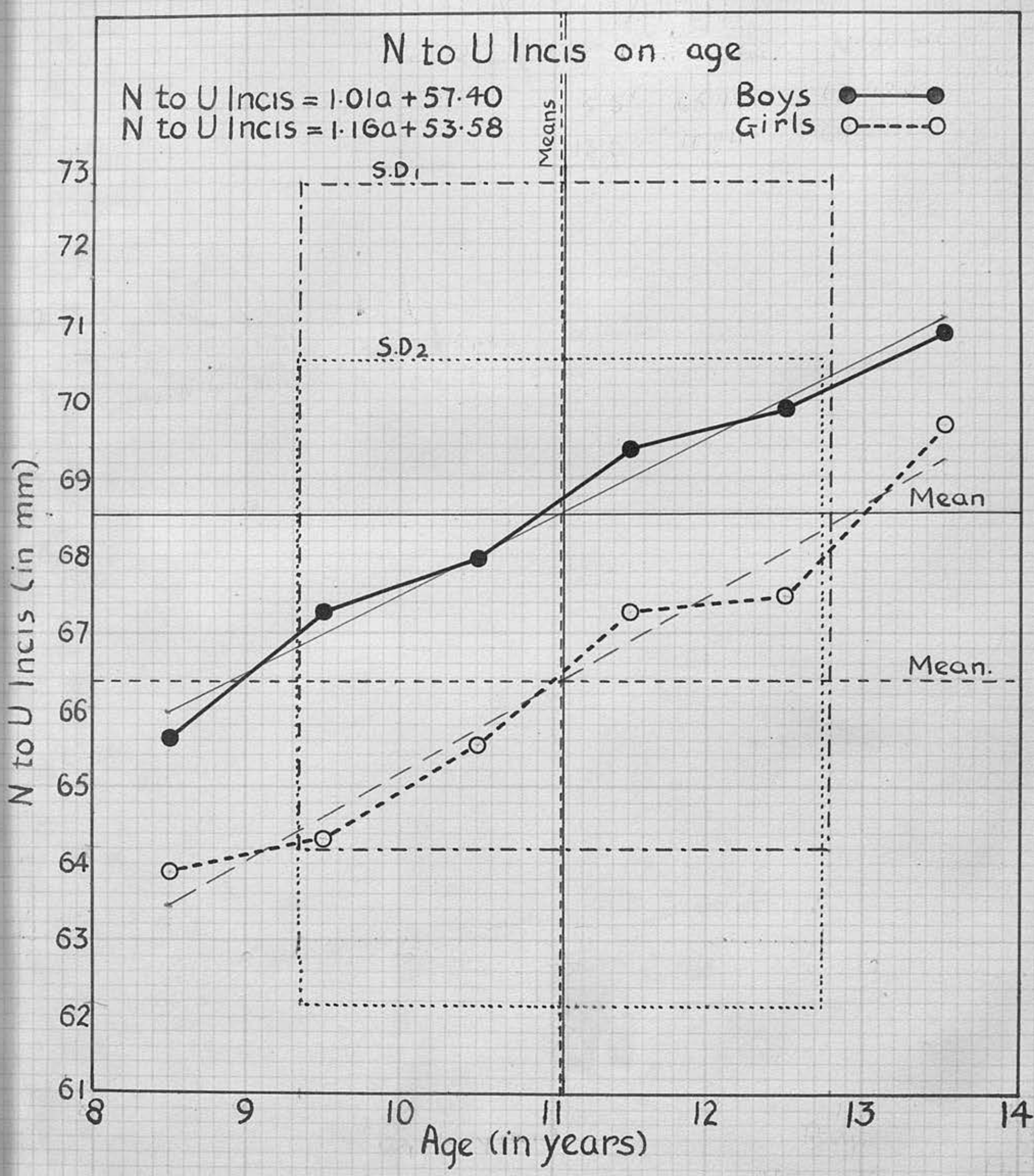
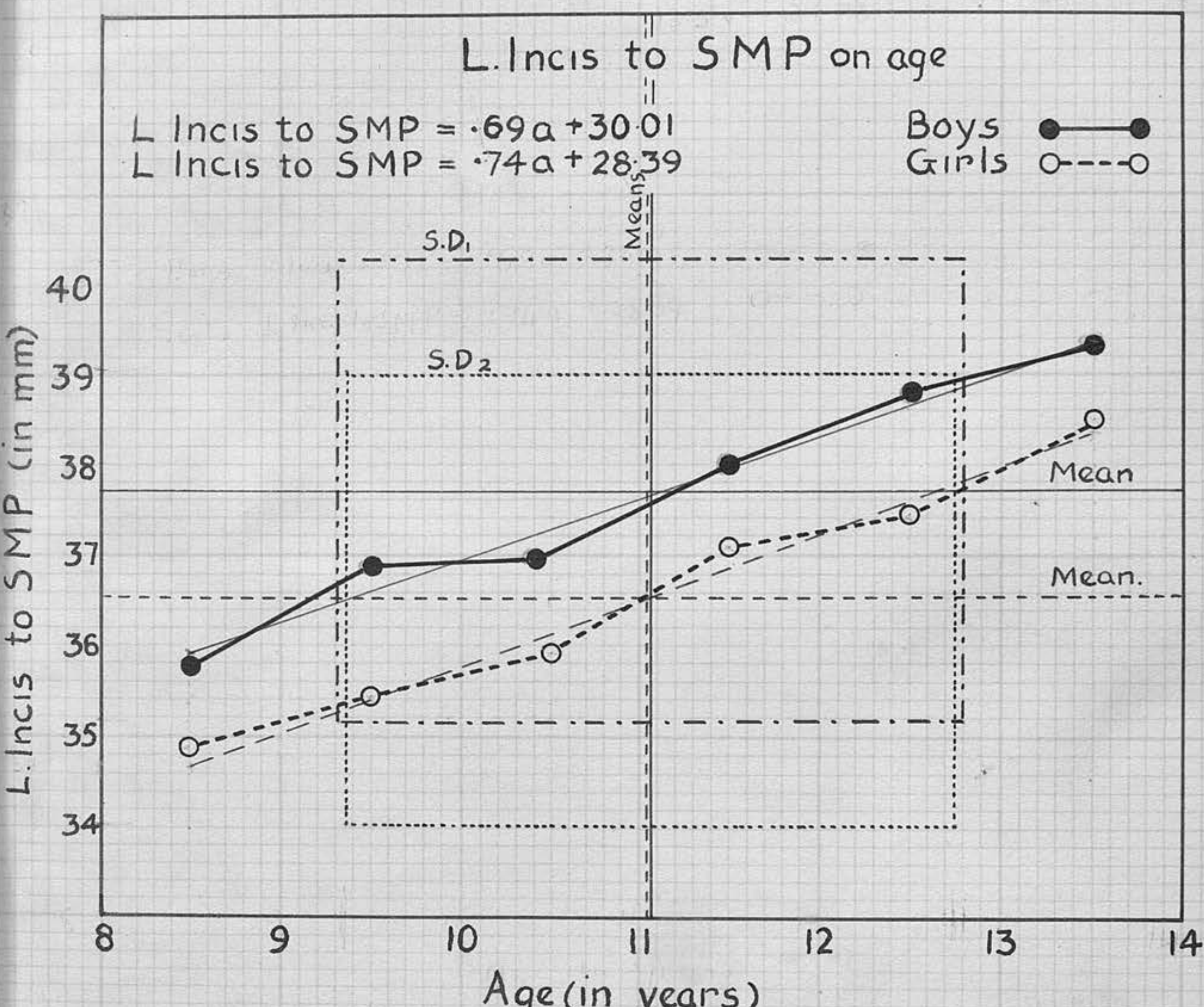
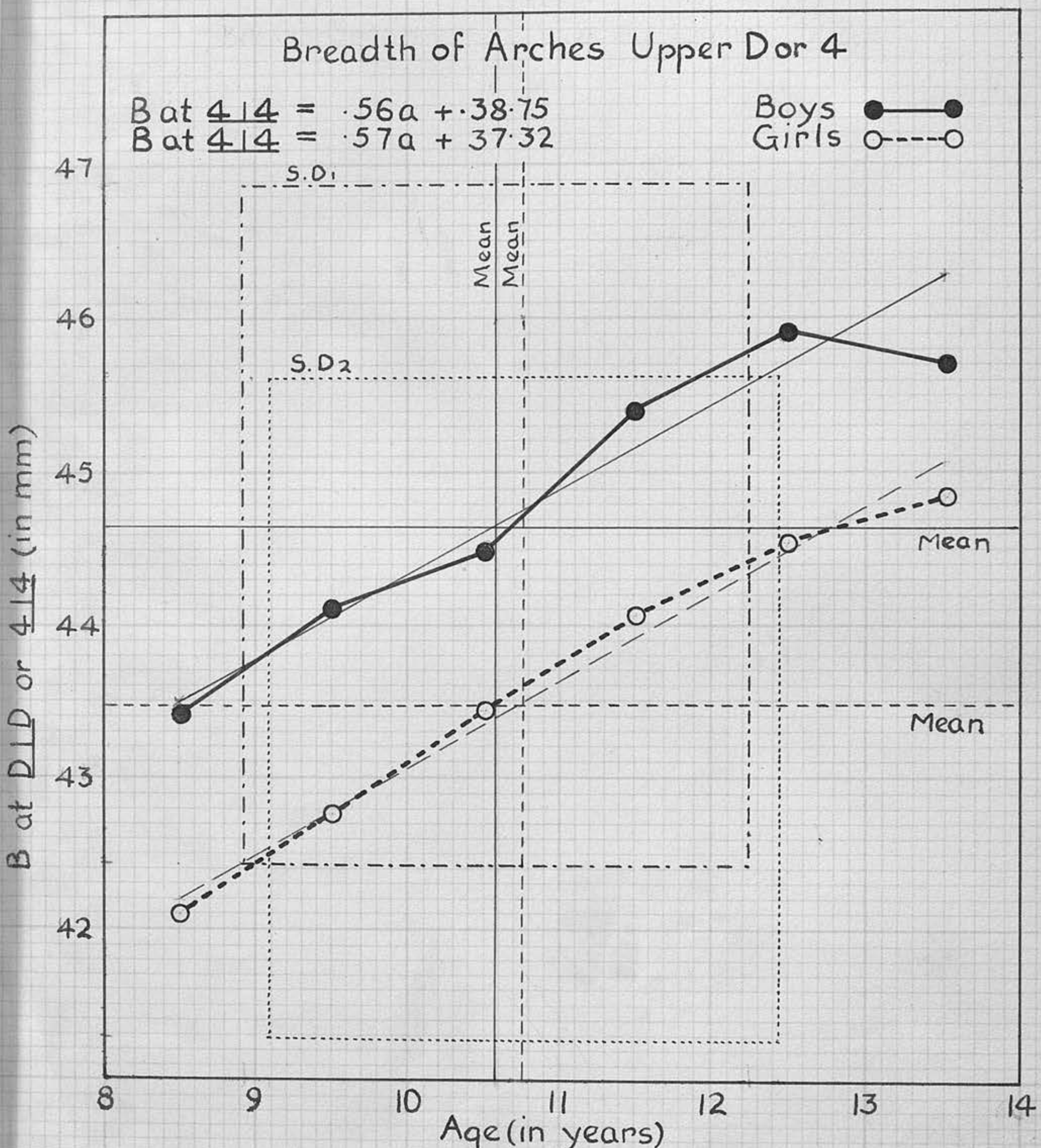

N to U Incis on age
N to U Incis = 1·01a + 57·40
N to U Incis = 1·16a + 53·58
Boys
Girls
Means
S.D1
S.D2
Mean
Mean.
N to U Incis (in mm)
Age (in years)
73
72
71
70
69
68
67
66
65
64
63
62
61
8
9
10
11
12
13
14

DIAGRAM 4



L. Incis to SMP on age
L Incis to SMP = ·69a + 30·01
L Incis to SMP = ·74a + 28·39
Boys
Girls
Means
S.D1
S.D2
Mean
Mean.
L. Incis to SMP (in mm)
40
39
38
37
36
35
34
8
9
10
11
12
13
14
Age (in years)

DIAGRAM 5



Breadth of Arches Upper D or 4
B at 4|4 = ·56a + ·38·75
B at 4|4 = ·57a + 37·32
Boys
Girls
S.D1
S.D2
Mean
Mean
Mean
Mean
47
46
45
44
43
42
B at D|D or 4|4 (in mm)
8
9
10
11
12
13
14
Age (in years)

DIAGRAM 6

with a view to their treatment. We wish to determine whether the measurement of a particular facial character may be considered abnormally in excess or in defect. The simplest method is to compare the individual measurement with the average value of that character in the corresponding age or stature groups shown in Tables 2, 3 and 4, the divergence in excess or in defect is divided by the standard deviation or average variability of the corresponding distribution.

If the ratio is 1, 1 child in 6 has the character more emphasised

if 1.5, 1 child in 14 or 15 " " " " "

if 2, only 1 child in 50 " " " " "

if 2.5 only 1 child in 100 " " " " "

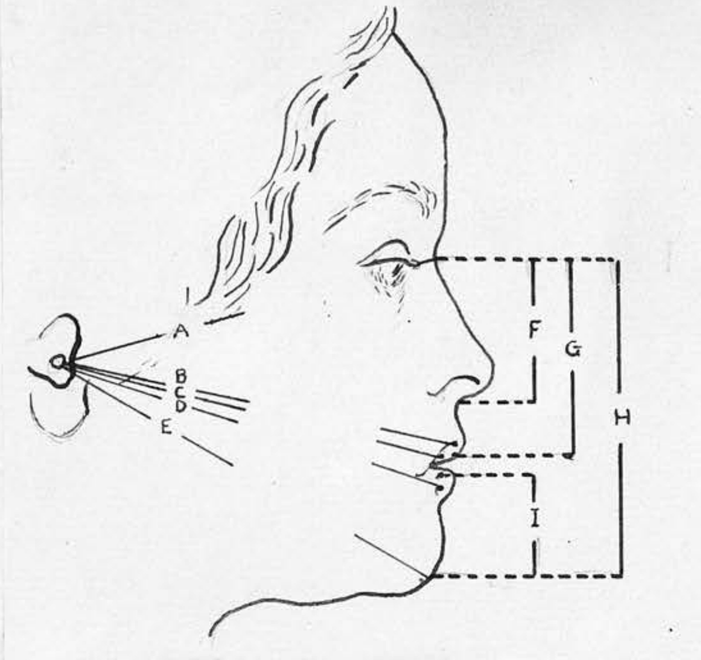
According to convention, a characteristic can hardly be spoken of as individually remarkable until it occurs only once in 50 or more children i.e. when the ratio equals at least 2. Values of 1 to 2 may be said quoting Professor Karl Pearson "to contribute something to individuality but not to be markedly personal features".

A second method of determining when any character may be regarded as abnormal is to use the regression equations expressing the mean value of the character in terms of age or stature to obtain the theoretical or predicted value of the character from the recorded age or from the recorded height of the child. The deviation of the value predicted in this way from the actual or observed value in the child is divided by the standard deviation or standard error of prediction
If the ratio is equal to or exceeds 2 the conclusion may again be drawn that the measurement of the particular character in the child is exceptional and not such as would be likely to occur fortuitously. In place of using the regression equation for age or height, regression equations expressing the character in terms of both age and stature may be applied for the purpose

of prediction. As nearly all the facial characters are fairly highly correlated with both these variables the use of the two variables together gives a better prediction than the use of either separately. It has been mentioned, and will be referred to more fully later that the body weight was found rather unexpectedly to be definitely more highly correlated with most of the characters than either age or height. It thus seemed to be advisable if not even essential to bring body weight into consideration and the best method of testing from the data available whether a measurement of a particular facial character in a child should be considered abnormally in excess or in defect seems to be to use a regression equation expressing the character in terms of age, stature and body weight and to compare the difference between the observed and predicted values with the standard error of prediction, again assuming a significant or sensible divergence from the normal if this ratio equals or exceeds 2. The necessary equations have been calculated but the enquiry has been restricted to the characters that appear in the profile view. The profile view is the aspect in which abnormalities are more obtrusive and variation from the normal in this aspect are most important and more frequently and more urgently call for correction for aesthetic reasons. Equations have thus been computed expressing in terms of 1. age and stature

2. age, stature and body weight

the following measurements: T A to N (A), T A to U I G M (B), T A to U I I M (C), T A to L I G M (D), T A to M P (E), N to S N P (F), N to U Incis (G), N to S M P (H), L Incis to L B M (I). These measurements are shown in the profile outline of the face given below.



The equations for the separate sexes for the age period 8-14 years with their standard errors of prediction are as follows:

Boys

	Equations	Standard error of prediction.
1	T A to N* = .46a + .14h + 65.57	3.42
2	T A to N = .35a + .08h + .12w + 70.02	3.40
1	T A to U I G M = .73a + .12h + 64.75	4.03
2	T A to U.I G M = .45a - .01h + .31w+76.01	3.93
1	T A to U I I M = .64a + .14h + 65.18	4.16
2	T A to U I I M = .37a + .02h + .29w+75.71	4.07
1	T A to L I G M = .79a + .12h + 64.33	4.03
2	T A to L I G M = .49a - .01h + .31w+75.87	3.91
1	T A to M P = 1.04a + .20h + 64.65	4.29
2	T A to M P = .68a + .03h + .39w+78.83	4.13
1	N to S N P = .12a + .13h + 24.35	3.30
2	N to S N P = .02a + .06h + .16w+29.87	3.25
1	N to U Incis = .27a + .17h + 42.11	3.65
2	N to U Incis = .05a + .07h + .26w+50.89	3.54
1	N to S M P = .54a + .25h + 63.10	4.80
2	N to S M P = .23a + .09h + .37w+75.76	4.63
1	L Incis to S M P = .27a + .09h + 21.87	2.15
2	L Incis to S M P = .14a + .03h + .15w+26.91	2.09

* In all the equations a = age in years
h = full stature in centimetres
w = body weight in kilograms

Girls

		Equations	Standard error of prediction.
1	T A to N	$= -.12a + .24h + 55.73$	3.37
2	T A to N	$= -.23a + .13h + .21w + 65.37$	3.30
1	T A to U I G M	$= .17a + .24h + 53.58$	3.92
2	T A to U I G M	$= -.05a + .03h + .39w + 71.60$	3.70
1	T A to U I I M	$= .26a + .23h + 55.67$	3.98
2	T A to U I I M	$= .03a + .01h + .34w + 76.29$	3.22
1	T A to L I G M	$= .25a + .23h + 53.63$	3.76
2	T A to L I G M	$= .02a + .02h + .40w + 72.34$	3.52
1	T A to M P	$= .28a + .34h + 51.70$	4.20
2	T A to M P	$= -.03a + .05h + .54w + 76.97$	3.79
1	N to S N P	$= .33a + .09h + 27.21$	3.03
2	N to S N P	$= .19a + .03h + .13w + 32.26$	2.99
1	N to U Incis	$= .40a + .15h + 42.04$	3.57
2	N to U Incis	$= .14a + .04h + .24w + 51.54$	3.46
1	N to S M P	$= .84a + .19h + 64.87$	4.70
2	N to S M P	$= .41a + .02h + .40w + 80.72$	4.45
1	L Incis to S M P	$= .45a + .06h + 23.96$	2.14
2	L Incis to S M P	$= .26a - .02h + .18w + 30.86$	2.04

For children in the age group 2-5 years taking boys and girls together similar equations have been calculated and are as follows:

		Equations	Standard error of prediction
1	T A to N	$= .11a + .16h + 64.23$	2.96
2	T A to N	$= -.09a + .05h + .54w + 67.21$	2.86
1	T A to U I G M	$= .06a + .22h + 56.64$	3.52
2	T A to U I G M	$= -.17a + .10h + .61w + 60.02$	3.41
1	T A to U I I M	$= .23a + .21h + 57.73$	3.44
2	T A to U I I M	$= .06a + .12h + .44w + 60.12$	3.38
1	T A to L I G M	$= 1.17a + .15h + 57.84$	3.77
2	T A to L I G M	$= .80a - .04h + .96w + 63.11$	3.50
1	T A to M P	$= .93a + .43h + 46.03$	3.76
2	T A to M P	$= -.39a + .24h + .95w + 51.41$	3.50
1	N to S N P	$= .67a + .18h + 15.67$	2.20
2	N to S N P	$= .63a + .15h + .11w + 16.29$	2.19
1	N to U Incis	$= 1.44a + .21h + 30.36$	2.59
2	N to U Incis	$= 1.42a + .20h + .05w + 30.62$	2.59
1	N to S M P	$= 1.04a + .41h + 42.66$	3.57
2	N to S M P	$= .81a + .29h + .61w + 46.04$	3.46
1	L Inc to S M P	$= .26a + .15h + 15.58$	1.68
2	L Inc to S M P	$= .10a + .07h + .42w + 17.88$	1.57

The application of these equations in testing whether a measurement of any facial character may be considered abnormal or not may be illustrated by the working of an example of a concrete case for the benefit of some of those who are rather too prone to imagine that they have great "difficulty" in understanding or making use of figures.

A child aged 4 years and 6 months has a stature of 108.0 cm and a weight of 19.8 kilograms, should it be considered abnormal in regard to the character L Incis to S M P ?

Using the equation No 2 at the foot of the previous table

L Inc to S M P = .10a + .07h + .42w + 17.88   we get

= .10×4.5+.07×108.0+.43×19.8+17.88

= 34.2 mm

The actual or observed value in this child is 32.5 mm

then 34.2 - 32.5 = 1.7

1.7 / 1.57 = 1.08

As the ratio of the deviation of the predicted value from the actual value divided by the standard error of prediction which is given in apposition to the equation in the table is less than 2, the measurement in the child may be considered to fall well within the normal range. Had the observed measurement in the child been only 31 mm

then 34.2 - 31.0 = 3.2

3.2 / 1.57 = 2.04

As the ratio now exceeds 2 the measurement is beyond the limits of what may be regarded as the range of the normal series.

If the body weight were not recorded but age and stature only stated then equation No 1 at the foot of the table would be applied

L Inc to S M P = .26a + .15h + 15.58

= .26×4.5+.15×108.0+15.58

= 33.0 mm

This predicted measurement deviates from the actual or observed value, 34.2 mm, by 1.2 mm, which divided by 1.68, the standard error of prediction when using this equation gives a ratio of 1.2 divided by 1.68 = 0.7. As the ratio is under 2 the conclusion would again be drawn that the character in the child is normal.

If the child were of an age between 8 and 14 years, the appropriate equation for the sex and the particular character under investigation given in the previous table should be used in the manner described. If only the stature or the age of the child is recorded the corresponding equation expressing the character in terms of age or height could be used. As these are 54 in number for the two groups of children at ages 2-5 and 8-14 years, they have not been tabulated, although they have been calculated, owing to considerations of space. Moreover, it has been stated already that a better prediction is obtained by using an equation involving the two variables than by the application of an equation based on either variable alone.

As the children in the main part of the investigation have been selected essentially because they exhibited the normal or ideal type of occlusion, it seemed very desirable to compare their facial measurements with those of a group of children taken at random from the general population. For this purpose the series of measurements already described were taken in 100 unselected boys in the age group 9-10 years. The mean values and variability of the facial characters in this series were compared with the corresponding values in the group of normal boys at the same age. The comparison is shown in Table 3. The two groups do not differ in mean age, mean stature, or mean body weight but they show a very distinct difference in their facial measurements. With a few exceptions the mean dimensions are less extensive in the normal group. In the five radial measurements T A to N, T A to U I G M, T A to U I I M, T A to L I G M and T A to M P the differences are very obvious. and as in all except the first, T A to N, they exceed twice their standard errors (in three of the characters they are four times this quantity) they are quite definitely statistically significant. The unselected boys have also greater mean zygomatic and bigonial facial breadths but the differences in these characters are not of such a degree that they can be considered sensible. With respect to vertical measurements the mean values of the N to U Inc, N to S M P, L Inc to S M P, L Mol to L B M are all greater in the random group but like the deviation in the breadths not significant whereas the mean value of N to 6 | 6 in the random group is sensibly greater than in the normal. The lengths of the upper and lower jaw are significantly greater in the unselected series. While too great emphasis should not be laid on the divergence observed in the breadth of the dental arches as, owing to numerous defects in the dental series of the random group the measurements therein cannot be considered very reliable, it cannot be regarded as a coincidence that the transverse dimensions of the dental arches are definitely greater in the random group in the region of 4 | 4, 6 | 6, and 6 | 6 and greater though not to a sensible degree at 4 | 4. The only two characters in which the random group shows the lower mean values are the palatal height in which the difference is significant and the N to S N P in which the difference is not sensible. In the two series, the upper facial index and the total facial index do not differ but the index of facial proportion (100 N to S N P/N to S M P) is significantly lower in the random group. The last relationship is but a reflection of the smaller N to S N P and greater N to S M P measurements in the unselected group. As the essential basis of the very stringent selection that has been made in collecting the normal group is the existence of a normal, anatomically correct or ideal type of occlusion and the difference between this group and a random group of the same average age, stature and body weight is, generally speaking, a diminution in the mean dimensions of nearly all the characters of the face and jaw that have been considered, it almost seems to suggest, though it would be rash to make a definite assertion to the effect on the evidence available, that the normal or ideal type of occlusion is usually a concomitant of a type of face which tends to be under the average in general size. It may be added in conclusion that while anatomically correct or ideal occlusion seem to be legitimate terms it is certainly a misnomer to apply the term normal to a type of "bite" which is found in less than 10 per cent of the ordinary child population as was elicited in the present investigation or 7.2 per cent as recorded by Meyer (1929).

From a survey of Table 1 it may be readily seen that there is generally a very close correspondence between the mean values of the facial characters in boys and girls at corresponding ages in the age period 2-5 years. In very few instances can such differences as are observed be regarded as statistically significant. Boys and girls have thus been taken together and the mean values and variability of the characters for children irrespective of sex have been tabulated for the ages 2-3, 3-4 and 4-5 years. By this procedure the further advantage is gained of having larger numbers of observations to deal with in each age group. The correlation coefficients to be referred to later and the regression equations already described for the age period 2-5 years are based on children irrespective of sex. By a comparison of the mean values of the facial characters at the respective ages 2-3 and 4-5 years in Table 1 and at ages 8-9 years and 13-14 years in Table 2 the degree of the increase in each character with age can be readily determined for the period for which data are available. The increase over the whole age period from 2-14 years can also be readily ascertained by comparing the mean values in Table 1 with the corresponding values in Table 2. In the age period 8-14 years all the characters with one notable exception, the length of the dental arch, exhibit a linear regression with age, that is the means of the arrays or the frequency distributions for the successive ages appear to be given to a satisfactory degree of approximation by straight lines. As already mentioned, this relationship has been tested and confirmed by comparing the coefficients of correlation and correlation ratios between the several characters and age by Blakeman's criterion.

It is impossible to describe in detail the increase with age of the complete series of facial characters and further consideration will, therefore, only be given to the character that does not increase with age, namely, the length of the dental arches and certain of the others in which the relationship to age is of most general interest such as the width of the dental arches and some indices which have been calculated, namely, the total facial index (100 N to S M P/Zyg B) and the index of facial proportion (100 N to S N P/N to S M P).

Length of the Dental Arch

The mode of measurement of this character has already been described (p. 3). It has also been mentioned that Franke (1921) uses the term "height" of the alveolar arch for what appears to be a closely corresponding measurement. The change or rather absence of change in this measurement with age has long been a subject of interest and discussion. It was first pointed out by John Hunter (1803) that after the age of 1 year, the jaw between the symphysis and the 6th tooth never increases in length. Tomes ( ) also drew attention to the fact that after complete eruption of the milk teeth the alveolar arch of the human lower jaw in the region previously occupied by them does not grow any more. Bolk (1924) states that the fact that the length of the set of the milk teeth in man is equivalent to that of the substituting teeth is but very little known in the literature though noticed by Hunter and referred to by Tomes. He states that he was able to confirm the accuracy of the fact that the alveolar arch of the human jaw does not grow after the second year. He states further, however, that between the second and the sixth year, the upper border lengthens somewhat as room has to be made for the first permanent molar then being formed. Between the second and the sixth year the upper border as well as the inferior border of the body of the mandible takes part in the growth in length. Between the sixth and thirteenth year the growth of the <u>pars alveolaris</u> of the human jaw comes to a stand-still. He supports his conclusion by mean measurements of the transversal diameter of the dental arch, the cord of the dental arch and the circumference of the alveolar arch in 75 infants and 50 adults. Franke (1921) gives measurements of the length (or height) of the alveolar arches for the separate ages. The length of the alveolar arch is defined as the distance of the apex of the arch at its intersection with the partition between the alveoli of the central incisors and the anterior breadth which is the transverse line joining the points where the mid-line of the alveolar arch cuts the partitions between the M_1 and the m_2 or Pm_2. The height of the alveolar arch measurement obviously corresponds closely with the length of the dental arch as defined in the present investigation. Though unable to obtain figures for the separate years* I have been able to obtain some averages for age groups compiled by Brash (1924) from Franke's figures. The mean figures for the length of the dental arches at successive ages in the present investigation are as follows:

* The figures for the individual years were obtained later from the graph published by Brash. They are shown in the table below.

L U A.

	M	F	M & F	Franke* alveolar arch "height"	M	F	M & F	Franke* alveolar arch "height"
2-	28.46(12)	27.96(13)	28.20(25)	24.7†	24.79(14)	24.88(13)	24.83(27)	21.3†
3-	28.29(17)	28.06(17)	28.18(34)	24.2	24.85(17)	24.41(17)	24.63(34)	21.7
4-5	28.56(18)	27.71(12)	28.22(30)	23.7	24.67(18)	24.19(13)	24.47(31)	21.7
2-5	28.44(47)	27.93(42)	28.20(89)	23.8 (2-7y.)	24.77(49)	24.49(43)	24.63(92)	21.5 (2-7y.)
8-	39.02(56)	38.39(56)		22.3†	34.93(56)	34.25(56)		21.3†
9-	39.63(55)	38.80(65)		22.3	35.20(55)	34.31(65)		22.0
10-	38.82(47)	38.89(56)		22.2	34.48(47)	33.93(56)		22.7
11-	38.91(17)	37.70(28)		22.0	33.74(17)	32.73(28)		21.3
12-	38.83.(12)	38.11(18)		21.8	32.83(12)	32.22(18)		19.8
13-14	36.94(9)	36.68(11)		21.8	32.33(9)	31.32(11)		20.0
8-14	39.03(196)	38.44(234)		22.1 (8-13y.)	34.55(196)	33.71(234)		21.2 (8-13y.)

† The figures for individual ages are read from Brash's graphs of Franke's data.

* taken from Brash (1924)

the numbers in brackets are the numbers of observations on which the averages are based.

It is obvious from these data for the successive ages that there is no increase in the length of either the upper or lower dental arch from age 2.5 years to age 4.5 years and no increase but even a slight suggestion of a tendency to fall from age 8.5 to age 13.5 years though the tendency to fall is possibly due to the fact that the averages at the higher ages cannot be considered very reliable as they are based on relatively small numbers. The difference in the length of the dental arch in the age group 2-5 years and the age group 8-14 years is the mesio-distal or antero-posterior diameter of the crown of the first permanent molar. Sir Arthur Keith (1924) gives an average value of 10.3 mm for this dimension in the upper jaw and 10.2 mm in the lower jaw based on measurements of 20 medical students at the London Hospital. Hrdlička (1923) for the first lower molar of American whites gives a mean measurement of 10.6 mm and for Egyptians 10.5mm. Topinard, quoted by Hrdlicka, gives a mean measurement of 10.5 mm for "Europeans". If 10.3 or 10.5 mm is added to the measurement in the age group 2 to 5 years to make it comparable with the measurement at 8 to 14 years, it is obvious that the length of the dental arch remains unchanged throughout the whole period of life, 2-14 years, covered by the investigation. These results thus supply ample confirmation of the observations of Hunter, Tomes and Bolk. The mean values of the length of the arch were calculated for the age groups 2-5 years and 8-14 years in order that comparison might be made with the figures from Franke quoted by Brash for approximately similar age groups. The results seem to indicate that such a comparison is not legitimate. Probably the discrepancy arises from the difference in the anterior point from which the measurement is taken.

Breadth of the dental arches.

The mode of measurement of the external breadth of the dental arches in the two regions D or 4 | 4 and 6 | 6 in the present investigation has already been described (p 3). There appear to be many different ways of estimating the transverse diameter of the dental arch and no two observers seem to adopt the same method or use the same points of contact for the measurement. The Committee, responsible for the collection of the data at present under review, began by taking internal measurements of the dental arch and decided later when the investigation was well under way that it would be preferable to collect the external measurements. Unfortunately, through a misunderstanding, no notice of the change in technique which had been agreed upon was conveyed to the observer at the time and she continued to take the internal measurements for many months thereafter. This conversion to another point of view is largely responsible for the fact that external measurements of the dental arch are not available for a relatively large proportion of the children at the higher ages. For this group the internal measurements are, however, recorded. In a certain proportion of the children both internal and external arch measurements were taken at the request of the writer but the number in this category is relatively small as the suggestion was made very late in the course of the enquiry.

From reference to Table 1 it may be readily seen that there is absolutely no increase in the mean external measurement of the upper dental arch at D|D and a slight but, in the data available, quite insignificant increase in mean value in the lower dental arch as children increase in mean age from 2.5 years to 4.5 years. As the mean age increases from 4.5 to 8.5 years, the upper arch at D|D or 4|4 increases in average value by 3.3 mm and the lower arch by 2.3 mm. These increases are definitely significant as they are at least five times their standard errors. From 8 to 14 years the increase in the mean transverse bicuspid diameter of the upper dental arch is 2.3 mm in boys and 2.7 mm in girls. These increases are also definitely statistically significant. In the lower arch the mean increase in the same age period is 2.2 mm in both boys and girls. These increases are again definitely sensible. The rate of increase seems to slow down or practically cease between certain ages and to accelerate somewhat at other age intervals but the time of these variations does not appear to be coincident in the two sexes or in the two jaws.

Between the mean ages 8.5 and 12.5 years the breadth of the upper dental arch at 6|6 shows a mean increase of 1.82 mm in boys and 1.86 mm in girls. In the lower jaw at the corresponding point the mean increase in the age interval from 8 to 14 years is 2.2 mm in girls as well as in boys. These gains are all statistically significant. The rate of increase in the region $\underline{6 \mid 6}$ seems to wax and wane as in the bicuspid region. The number of observations in boys at ages 13-14 years is relatively small for the reason already referred to and is probably inadequate to give stable mean values. This fact may be responsible in some degree for the absence of any increase in average dental arch breadth in boys between the ages of 12 and 13 whereas growth in extent appears to continue in this age interval without interruption in girls for whom larger numbers are available.

The growth in width of the dental arch appears to conform to some extent though not at all age periods with the type of growth curve described by Harris (1931) as representing the change in height and body weight with increasing age. There is apparently no growth at ages 2-5 years which is referred to by this observer as the <u>first filling-out</u> period in which growth in height is slow and steady. There is evidence of a distinct gain in width, however, from 5 to 8 years, the <u>second springing-up</u> period. More or less steady growth is exhibited between seven and eleven or twelve years according to the sex. This is the <u>second filling-out</u> period with steady growth in height as its characteristic. The third <u>springing-up period</u> associated with puberty which follows is not, however, so far as the data show, accompanied by any significant increase in the transverse dimensions of the dental arch.

Owing to the lack of agreement as to points of measurement adopted by different observers in measuring the width of the dental arch which has already been referred to, it is not possible to obtain mean measurements of the character which corresponds exactly with the results obtained in the present inquiry. Lewis and Lehman (1929) publish for half-yearly age groups in children from 2 to 9 years of age mean measurements of the transverse dimensions of the arch in the region of the first deciduous molars and its variability. The points of contact for measurement in the upper arch are "the points of the lingual cusps of the first deciduous molars" and in the lower arch "the distal fossae of the first deciduous molars". These points of measurement they adopted on the advice of Milo Hellman whom they called into consultation in the solution of their problem as to the best method of measurement. The measurements are based on fairly adequate numbers of children and though they do not exactly correspond with the measurements taken in the present enquiry an attempt has been made to make use of them for purposes of comparison of the type of growth exhibited. The means and their standard errors as well as the variability of the characters have therefore been calculated for yearly age groups. They are shown below in apposition with the results obtained in the present investigation.

	B at D | D (in mm)			B at D | D (in mm)		
ge (years)	Lewis & Lehman	Present inquiry.	New values	Lewis & Lehman	Present inquiry	New values
2-	28.62 0.26	39.74 0.30	—	28.68 0.22	35.89 0.26	—
	1.85	1.77		1.61	1.49	
	51	34		52	34	
3-	28.84 0.16	39.93 0.27	28.81	28.83 0.15	35.94 0.25	28.73
	1.71	1.53		1.69	1.43	
	122	33		122	32	
4-	29.03 0.14	40.13 0.37	29.01	28.86 0.16	35.78 0.34	28.57
	1.52	2.07		1.75	1.83	
	121	31		121	31	
5-	29.18 0.17	-		28.86 0.19	-	
	1.52			1.67		
	79			75		
6-	29.20 0.24	-		28.81 0.20	-	
	1.58			1.27		
	42			40		
7-	30.15 0.34	-		29.73 0.32	-	
	1.62			1.58		
	23			24		
8-9	30.68 0.45	42.70 0.18	31.58	30.10 0.35	37.37 0.14	30.16
	1.86	2.05		1.34	1.64	
	17	130*		15	131*	

* deciduous teeth only.

If we assume that the differences in the mean measurements at age 2 years namely 11.12 mm in the upper arch and 7.21 mm in the lower arch give the mean measurements of the extent of the transverse diameters of the first deciduous molars that constitutes the difference due to the two modes of measurement, this obviously remains constant for the succeeding ages as it is a tooth character and the values can be deducted from the measurements obtained in the present inquiry to make them correspond with the actual mean values tabulated by Lewis and Lehman. The results of such a procedure are shown in detail in the previous table and are given more briefly below:

	B at $\underline{D \mid D}$ (in mm)		B at $\overline{D \mid D}$ (in mm)	
Ages (years)	Lewis & Lehman	Adjusted or new values	Lewis & Lehman.	Adjusted or new values.
3-4	28.8	28.8	28.8	28.7
4-5	29.0	29.0	28.9	28.6
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
8-9	30.7	31.6	30.1	30.2

In all except $\underline{D \mid D}$ at age 8 years the figures are practically identical. In $\underline{D \mid D}$ at 8 years, the slight difference observed is not statistically significant and as the average of Lewis and Lehman is based on only 17 observations it cannot be regarded as stable or representative. The figures published by Lewis and Lehman for the mean breadths of the upper and lower dental arches at $\underline{D \mid D}$ and $\overline{D \mid D}$ respectively in American children from the Merrill-Palmer school at the ages 3-4, 4-5 and 8-9 years are thus practically identical with the corresponding values obtained in the present inquiry when the proper adjustment is made for the difference in method of measurement.

Professor Brash in his second lecture delivered under the auspices of the Dental Board of the United Kingdom in 1924 discusses in detail the changes in the breadth of the dental arch with age and its average rate of growth. He makes use of such figures relating to the subject as had been published by different authors and were available at that time. Unfortunately though the number of authors cited as having made observations on this point is fairly large, the number of cases observed on the other hand is exceedingly small. While one of the authors, Sir F Colyer, seems to have published records of six cases which he has measured over a period of years most of the authors base their conclusions on one or two cases. It is obvious that little emphasis can be laid on a general average based on such a heterogeneous collection of, for the most part, isolated cases. Brash, while completely aware of the limitations of the data and the inadequacy of the numbers to justify statistical conclusions; for lack of more suitable material averages the series and concludes that the average increase in the dental arches per year from $3\frac{1}{2}$ to 16 years may be taken as 0.42mm in the maxilla and 0.35 mm in the mandible. From 3.5 to 13.5 years, i.e. 10 years, in the data for boys in the present enquiry the average annual increment at $\underline{4 | 4}$ is 0.51 mm in the maxilla and 0.37 mm in the mandible. These values do not diverge. Brash's figures may thus be regarded as a fairly good approximation.

Brash in the lecture referred to also makes a detailed analysis of the figures published by Franke of Berlin relating to the growth in width of the alveolar arch and publishes graphs which he has constructed from these showing the mean values for successive years of life. As already mentioned, I have not been able to obtain Franke's book for reference. From the graphs published by Brash, however, I have read off as accurately as possible the mean values of Franke's "middle breadth of the alveolar arch". The graphs have unfortunately only been reproduced in a small scale and the extraction of the values presented a little difficulty but complete confidence can be placed in their approximate accuracy. Franke's "middle breadth of the alveolar arch" is the transverse breadth joining the centres of the alveoli of the first permanent molars and its increase indicates the actual separation of the M_1. It should be possible to compare this measurement at the different ages with the width of the dental arch at 6|6 in the present inquiry and the result of an attempt to do so is shown below.

	Maxilla			Mandible		
ge in ears)	Present inquiry Mean Ext. breadth of dental arch at 6 6(mm) (1)	Franke Mean "middle breadth" of alveolar arch. (2)	New or adjusted values in present inquiry. (3)	Present inquiry Mean Ext. breadth of dental arch at 6 6(mm) (4)	Franke Mean "middle breadth of alveolar arch. (5)	New or adjusted valuesin present inquiry. (6)
-9	54.5(156)	43.7*	-	52.8(156)	44.7*	-
-10	54.8(152)	44.0	44.0	52.9(152)	45.0	44.8
0-11	55.2(128)	44.3	44.4	53.2(128)	45.3	45.1
1-12	55.8(119)	44.7	45.0	53.7(118)	45.5	45.6
2-13	56.4(126)	45.0	45.6	54.1(126)	45.7	46.0
3-14	56.2(76)	44.7	45.4	53.9(76)	46.0	45.8

* Values read from Brash's graphs of Franke's data.

If we assume as with the Merrill-Palmer data at ages 2-3 years that the difference in the mean values at age 8-9 gives the extent of the first molar teeth that constitutes the difference in the mode of measurement, then the average value should remain constant at the successive ages as it is a tooth measurement which does not change with age. The difference in the measurements for the maxilla is 10.8mm and for the mandible 8.1mm. By deducting these quantities from the mean measurements for maxilla and mandible at the succeeding ages, the values obtained should be comparable with the mean values obtained from Franke's figures. The results are shown in the table. It will be seen from comparison of columns 2 and 3 and 5 and 6 that there is a remarkable correspondence in the new or adjusted values for the data in the present inquiry and Franke's mean figures. As there is no reference to the sex of the skulls on which Franke's mean values are based, the skulls are referred to as those of "persons", the mean figuresin the data from the present inquiry are computed for boys and girls. Considering the fact that the number of skulls and the proportion of each sex comprising the groups on which Franke's averages for each age are based are unknown such differences as are apparent might easily arise from small numbers in these or a difference in sexual proportion in the two sets of data. It will thus be seen that it has been possible to compare the results relating to the breadth of the dental arch obtained in the present investigation with Franke's alveolar arch breadth at ages 8-14 years and with Lewis and Lehman's measurements of the dental arch at age 2-9 years and that these results are almost in complete harmony with the results obtained in the German and American children. It is perhaps worthy of mention that Franke's mean alveolar arch measurements for the maxilla show the same lack of growth in width from age 12-13 years that has been mentioned as a feature in the data for London school children. A brief reference may be made to the internal measurements of the dental arch at $\underline{6|6}$ and $\overline{6|6}$. They may be compared with Frank's mean measurements of the alveolar arch in a similar manner. The results are shown below:

	Franke. Mean "middle breadth of alv. arch.	Present inquiry. Mean internal breadth of dental arch at 6 | 6	Adjusted values in present inquiry.	Franke. Mean "middle breadth" of alv. arch.	Present inquiry. Mean internal breadth of dental arch at 6 | 6	Adjusted values in present inquiry.
	(1)	(2)	(3)	(4)	(5)	(6)
8-	43.7	33.9	-	44.7	32.5	-
9-	44.0	34.2	34.2	45.0	32.7	32.8
0-	44.3	35.1	34.5	45.3	33.2	33.1
1-	44.7	35.1	34.9	45.5	33.1	33.3
2-	45.0	35.2	35.2	45.7	33.1	33.5
3-14	44.7	35.8	35.9	46.0	33.3	33.8

The internal measurements of the dental arch at 6 | 6 and 6 | 6 in the 8-9 year old group of children of both sexes are respectively 9.8 mm and 12.2 mm less than Franke's mean measurements for the "middle breadth" of the alveolar arch at the same age. Deducting these quantities from Franke's measurements at the succeeding ages 9 to 13 years gives adjusted values for the figures obtained in this inquiry which exhibit a rather remarkable degree of resemblance to the actual mean dimensions of the dental arch at corresponding ages when allowance is made for possible differences in the numbers of observations available and sexual proportions in Franke's data and in the data obtained in the present inquiry.

As the first pre-molar of the permanent teeth, which replaces the first molar of the deciduous set is very different in its form and dimensions, it seemed to be very desirable to determine if possible the effect the change produced in the mean external transverse measurement of the dental arch at D | D or 4 | 4 and D | D or 4 | 4 . For this purpose the measurements of the arch were taken out in the age group 9 to 10.5 years in the separate sexes for the sub-groups of children possessing D | D and 4 | 4 . The mean values and their standard errors have been calculated for the two sub-groups and the comparison is shown below:

External Transverse Breadths of Upper and Lower Dental Arches in age group 9-10.5 years.

	Maxilla		Mandible	
	Boys	Girls	Boys	Girls
$\underline{D \mid D}$ or $\overline{D \mid D}$ present	43.61±0.26 2.03 63	42.19±0.20 1.55 58	38.21±0.18 1.40 59	36.68±0.21 1.55 56
$\underline{4 \mid 4}$ or $\overline{4 \mid 4}$ present	45.60±0.36 1.63 21	43.56±0.23 1.55 47	39.92±0.34 1.88 31	38.76±0.18 1.25 47
Differences	1.99±0.44	1.37±0.30	1.71±0.38	2.08±0.28

As the excesses in mean value for both sexes in the sub-groups where $\underline{4 \mid 4}$ is present are all considerably in excess of twice their standard errors, they must be considered to be quite definitely statistically significant. The mean age may be slightly higher in the children comprising these sub-groups than in the other sub-groups where $\underline{D \mid D}$ is present but such a difference in mean age as may exist would not account for the divergence observed. The mean external measurements of the dental arches in the region D or 4 are greater in those with the premolars than in those with the deciduous molars present.

The results of the present enquiry seem to indicate quite definitely that the dental arches increase in transverse diameter with age in the age interval 8-14 years although they do not increase in length. The opinion that the arch takes a wider curve appears, according to Professor Brash, to have been expressed by Thomas Bell (of Guy's Hospital who wrote the notes to Hunter's "Natural History of the Teeth" in Palmer's 1837 edition) as long ago as 1829. Since then the increase in dental arch breadth has been described by various observers among whom may be mentioned Zsigmondy of Vienna, Sir Charles Tomes (1892) and Sir Frank Colyer (1920).

As the mean external measurements of the transverse diameter of the upper dental arch at $\underline{4 \mid 4}$ only increase from 40.6 to 45.7 mm or 5.1 mm in boys and from 39.4 to 44.8 or 5.4 mm in girls in the age interval from 4 to 14 years it seems quite clear that the estimated increase in width at the median palatal suture during the eruption of the permanent dentition by Keith and Campion (1922) at 8 mm is excessive as has been already suggested by Brash (1924).

Facial Indices.

A change in the relative proportions of the length and breadth of the face which is expressed by the total facial index (100 N to S M P/Zyg B) has been referred to by Brash (1924). He quotes figures of facial length and breadth at successive ages from 6 years upwards in Schaffhausen boys and girls, taken from Schwerz who apparently extracted them from Martin (1914) and corresponding measurements of children from St.Louis collected by Porter whose figures are quoted by Martin. From these measurements of facial length and breadth I have calculated the indices from 8 to 14 years and they are shown below in apposition with the values obtained in the London school children:

	Boys.			Girls		
Age	Schaffhausen (Schwerz)	St.Louis (Porter)	London (Smyth)	Schaffhausen (schwerz)	St.Louis (Porter)	London (Smyth)
8-	86.4	83.3	82.0±0.41	86.3	83.1	81.8±0.42
9-	86.8	82.8	82.9	86.4	82.5	8. 8
10-	87.7	83.7	82.8	88.2	83.5	82.0
11-	87.8	83.9	83.8	87.6	85.2	83.2
12-	87.2	84.1	83.9	88.6	85.5	82.5
13-14	89.7	85.0	85.2±0.42	89.5	85.7	84.1±0.38

The indices for the London children show like the others that the length of the face definitely increases as compared with the breadth between the ages 8 and 14 years. There is, however, no change in the relative proportions of the face in the vertical direction, namely, nasal and infranasal in the same age interval as may be seen from the values of the index of facial proportion (100 N to S N P/N to S M P) for the successive ages in the London school children.

Ages.	8-	9-	10-	11-	12-	13-14
Boys.	42.1	42.2	42.4	42.2	42.2	42.2
Girls.	42.4	42.4	42.9	42.3	42.4	42.6

Interrelationship of the Facial Characters.

The provision of the mean measurements of the several facial characters and their standard errors with the standard deviations of the distributions at the different ages and for the different stature groups fulfilled the main purpose of the investigation, namely, to establish normal standards or norms for the several characters. The records of measurements provide also, however, valuable material ready to hand for the determination of the degree of association or relationship exhibited between each of the several pairs of characters, a knowledge of which may be of value in throwing further light on the normal growth of the face including the jaws in childhood. Accordingly, a fairly long series of correlation coefficients and correlation ratios were calculated. These are shown in the series of tables from Table VI onwards. For each character and age in the records and for a representative number of the characters and height in the records both correlation coefficients and correlation ratios were computed. Both are measures of the degree or intensity of association between two variables and from the divergence in the squares of the two values in any special case it is possible, by the aid of a simple formula, Blakeman's (1905), to determine if the relationship of the one character to the other is linear. If the relationship is non-linear, then the correlation ratio is a better measure of the intensity of the association that exists between the characters than the correlation coefficient. It is very important to know whether the relationship of the characters to age and height, or as it is generally described, the regression of the characters on age or height is linear as it is only in such circumstances that the graphs of the characters on age or height can be represented adequately by straight lines. Moreover, it was necessary to eliminate the influence of increasing age in determining the correlation between the characters and the method of partial correlation can only be legitimately used for this purpose if the regression is linear. The coefficients of correlation (r) and correlation ratios (n) between the corresponding characters and age and height are shown in Tables 7 and 8 The correlation ratios are stated to be corrected. This term indicates that an adjustment has been made in their values to correct for the number of arrays or rows in the tables from which they are calculated.

The linearity of the regression in the different cases has been tested by Blakeman's (1906) formula, i.e. $\zeta = \eta^2 - r^2$ has been compared with its standard error with the result that practically all the characters may be considered to be linearly related to age and height. It will be seen that the coefficients of correlation between certain characters and age and height respectively are very similar in value; in other cases, there is some divergence the excess being sometimes in favour of height and sometimes in favour of age. This tendency to similarity in degree of association between the characters and age and height respectively might be expected from the fact that the correlation between age and height is relatively high, the correlation coefficients between the variables being 0.738 in the boys and 0.772 in the girls, the corresponding corrected correlation ratios being 0.739 and 0.778. Comparison of these corresponding coefficients and ratios shows that within the age period considered in these data stature may also be considered to present a linear relationship to age although for a rather more extended age period this relationship would most probably not be maintained.

Reference has already been made to the fact that the intensity of the association between many of the facial characters and the body weight was found rather unexpectedly to be definitely higher than that between the corresponding characters and either age or stature. This sequence does not obtain invariably in regard to the characters which were tested but the tendency is clearly shown in all the three groups, children from 2-5 years, boys from 8-14 years and girls from 8-14 years and appears to hold for such measurements as the zygomatic breadth and the palatal height as well as the measurements seen in profile. The predominance of the association with body weight is clearly brought out in Table 9 where it is shown that the correlation between the several facial characters seen in the profile view with age or stature become insignificant or vanish when stature and body weight in the first instance and age and body weight in the second instance are held constant whereas the majority of the coefficients indicating the degree of association between the profile facial characters and the body weight when age and stature are held constant are statistically sensible in each of the three groups of children and usually of quite an appreciable size. The importance of including body weight in the regression equations for predicting the facial measurements from the age and dimensions of the child is thus clearly indicated. It has been assumed that the f acial characters seen in profile exhibit a linear relationship with body weight in the age period under review. Their linearity or otherwise has not been tested by calculating correlation ratios as was done in the case of the variables age and stature owing to lack of time but in any case which may be non linear the true correlation between the character and body weight as represented by the correlation ratio (η) will be higher than that actually tabulated for the coefficient ($\underline{r}$).

The correlation coefficients between the various pairs of facial characters that have been calculated to determine their interrelationship are shown in Table 10 and the partial correlation coefficients which show the intensity of the association which persists in the several cases when the influence of increasing age is eliminated are given in Table 11 for the three separate groups, children from 2-5 years, boys from 8-14 years and girls from 8-14 years. Reference to Table 11, shows that the values of the corresponding correlations in the two sex groups are usually in fairly close agreement. Between certain pairs of characters or variables the correlation that exists is of considerable intensity. Thus the correlation coefficient between the distances N to U Incis and N to $\underline{6 \mid 6}$ is approximately 0.8 in the three sub-groups, children from 2-5 and boys and girls from 8-14 years while that between the characters or measuremnts L Inc to S M P and L Mol to L B M is about 0.7. Approximately similar values are found for both these relationships in the group of 100 unselected boys at ages 9-10 years. The correlation coefficients between the distances N to U Incis and L Incis to S M P and between N to $\underline{6 \mid 6}$ and L Mol to L B M which are respectively in the same vertical planes but are measurements of the upper and lower face or mandible are definitely lower in all the groups (all except one are under 0.5) than those found between N to U Incis and N to $\underline{6 \mid 6}$ and L Incis to S M P and L Mol to L B M, the first two of which relate to the upper face, mainly the maxilla and the last two to the lower face or mandible. The correlations between the various absolute measurements of the dental arches are also, as might be expected, of a relatively high magnitude. Thus the coefficient between the external width of the dental arch at $\underline{6 \mid 6}$ (upper) and $\overline{6 \mid 6}$ (lower) is approximately 0.8 in both boys and girls and that between the external width at $\underline{4 \mid 4}$ (upper) and $\overline{4 \mid 4}$ (lower) approximately 0.7. The correlation between the widths at $\underline{4 \mid 4}$ (upper) and $\underline{6 \mid 6}$ (upper) exceeds 0.6. The correlation between L U A and L L A exceeds 0.7 in normal girls, normal boys and unselected boys at age 9-10 and falls just below 0.7 in children from 2.5 years. It has been already mentioned that in a certain proportion of the children from 8-14 years both internal and external measurements of the dental arch were taken. Both measurements were available for about 50 boys and a somewhat smaller number of girls. Correlation coefficients between the internal and external measurements in the four regions where the jaws were measured. The coefficients were calculated for boys and for boys and girls together. They are shown below:

	Internal and Ext. measurements at $\underline{4 \quad 4}$	Internal and Ext. measurements at $\underline{6 \quad 6}$	Internal and Ext. measurements at $\overline{4 \quad 4}$	Internal and Ext. measurements at $\overline{6 \quad 6}$
Boys	$.607 \pm .091$ (48)	$.856 \pm .073$ (50)	$.749 \pm .097$ (47)	$.803 \pm .084$ (50)
Boys and Girls	$.673 \pm .085$ (75)	$.848 \pm .059$ (80)	$.761 \pm .075$ (74)	$.785 \pm .070$ (79)

The degree of association is relatively high as often occurs when one measurement overlaps or includes another with which it is correlated. The inclusion of the girls makes no appreciable change in the value of the coefficient shown for boys alone. The internal measurement forms on the average roughly 60% of the external measurement and the two seem to be in linear relationship with one another. With such relatively high coefficients expressing the degree of association between them it should be possible to obtain a regression formula which would express either measurement in terms of the other with a fair degree of accuracy.

Some of the remaining correlation coefficients in Table 11, though considerably smaller than those already referred to, nevertheless indicate very interesting relationships. Thus the height of the palate has a slight but significant positive association represented by a coefficient of 0.26 in boys and 0.36 in girls with N to U Incis or the distance between the nasion and upper incisors, in other words, the height of the upper face. The palatal height has also a very slight positive but significant association with the upper facial index (100 N to U Incis/Zyg B) in the groups of selected and unselected boys and in the girls though there appears to be no association between these two variables in children at 2.5 years. A relatively long face thus shows a very slight tendency to be accompanied by a relatively high palate. The height of the palate shows, however, no appreciable association with the width of the dental arches at $\underline{6|6}$ in either normal or unselectedboys though there is a very slight positive but sensible correlation between these variables in the group of normal girls.

It is difficult if not impossible to obtain in the literature any reliable results that are comparable with the quantitative measures of association as represented by r between different pairs of facial characters shown in the present investigation. Meyer (1929) of Basle in a paper extending to 74 pages entitled "Biometric Researches of Anatomically Correct Occlusion", a title which arouses considerable hope of finding something tangible devotes as much space to the discription of the methods of calculating the standard deviation and correlation coefficient as if they were recent discoveries whereas a knowledge of this procedure has been taken for granted for many years by all those interested in the subject. He completes his description by calculating and placing on record one correlation coefficient cited more or less as ah example. This is the correlation between the zygomatic diameter and the width of the upper dental arch at the 1st molars. He finds the value to be 0.183±·067. The coefficient is based on 95 observations which comprise both boys and girls from 4 to 17 years of age. As the value does not exceed three times its probable error he draws the conventional conclusion that it cannot be considered statistically significant. In the present enquiry the corresponding correlation <u>when corrected for age</u> and based on almost four times the number of observations is definitely significant. As will be seen from Table 11, it almost reaches 0.5 in the group of <u>normal</u> girls from 8-14 years and almost 0.4 in <u>normal</u> boys in the same age interval. In the group of 95 unselected boys at ages 9-10 years the coefficient is 0.49 and is at least six times its standard error. Apparently Meyer's value of the coefficient for the relationship cannot be accepted as truly representative. It may be mentioned that Meyer gives for the separate ages taking boys and girls togwther mean measurements of many facial characters which are considered in the present inquiry. For all ages, however, from 4-17 years, he has tecords of only 100 children with anatomically correct occlusion which were selected out of 1592 children examined and all the averages for individual years up to age 12 are based on numbers varying from 1-3 observations. For the group age 12 years there are 12 observations

"	"	" 13	"	comprises	23	"
"	"	" 14	"	"	30	"
"	"	" 15	"	"	13	"

At each of the ages 16 and 17 years there are three observations. The mean values for the ages 12 and 13 years could only be compared with the corresponding values in the present investigation and considering the small numbers on which the values depend it seemed scarcely worth the trouble of calculating the corresponding means for children irrespective of sex in the data under review to institute a proper comparison at these two age periods.

Korkhaus ( ) discusses at considerable length the question of the possible influence of surrounding portions of the skeleton of the face on the developing upper jaw. He states that "it was concluded from the fact that brachycephalic or euryprosopic races (Mongol races) have flat, broad and short palates and dental arches, while on the other hand dolichocephalic or leptoprosopic races (Ethiopian races) have high, narrow, long palates and dental arches that there is a similar relationship between the shape of the dental arch and the shape of the face in our population". He states further that Franke and Martin have denied the existence of such a correlation but that Berger on the basis of an examination of 30 persons with perfect dentition considers we may assume its existence at least as far as the posterior breadth of the dental arch and the zygomatic breadth are concerned. Korkhaus agrees with R Schwarz that Berger's material, namely 30 individuals, is far too small. He states that Linder and Harth have tested the correlation found by Berger and that their result based on 53 <u>normal</u> persons between the ages of 16 and 18 years leads to a conclusion at variance with his. Korkhaus states that Izard (Paris) established the existence of a correlation between the breadth of the dental arch and the breadth of the face by a complicated technique involving the construction of ellipses but that his conclusion was not confirmed by Linder and Harth who applied certain tests to his results. The values for the breadth of the jaw show only "a very qualified and gradual increase in regard to the breadth of the zygion so that the connection between the zygomatic breadth and the breadth of the dental arches must be regarded as highly doubtful". Korkhaus concludes finally that "for our mixed race, therefore, the racial characteristics do not hold good in so far as a correspondence between a long face and a narrow palate (upper jaw ellipse) or between a broad face and wide, flat dental arch is concerned". This conclusion he states is based on the findings of the anthropologists mentioned and quotes Williams as having already expressed a similar point of view. Korkhaus states he could reach no other conclusion in examining the skulls of the Bonn School of Anatomy. He shows in a figure (Fig 537) two skulls with normally rounded dental arches and very similar skull measurements, in which the breadth of the dental arches and the palate show quite remarkable differences. He also tabulates, to emphasise the contrast, the individual measurements in these two cases. Korkhaus states that the reason for variations in the shape of the dental arches is easily recognised to be the varying size of the crowns of the teeth and that in the mutual influence of the different factors which influence the growth of the dental arch and decree its shape, the breadth of the teeth appears to play a very important part. Korkhaus reproduces in a figure (No 536) an illustration taken from Williams of photographs of two individuals with quite differently shaped faces who

who nevertheless possess dental arches of the same dimensions. Despite Korkhaus's conclusion, the results of the present investigation which are based on adequate data show quite unequivocally that there is a very definite correlation between the zygomatic breadth and breadth of the dental arches at 6|6 . The correlation coefficient is still as high as 0.4 to 0.5 in all the three groups of children examined when the influence of increasing age is eliminated. Berger, therefore, was correct in his conclusion even though it was based on as small a number as 30 observations. Berger's data while demonstrating an association between the breadth of the face and the width at 6|6 seem to indicate that there is no relationship between the breadth of the face and the widthof the dental arch in the premolar region. In table 11 the correlation coefficient between these two variables is only shown for the group of childrsn at ages 2-5. In this group the coefficient when corrected for age is 0.32±.09 which is definitely significant as it exceeds three times its standard error. For the other groups the correlation has not been calculated but in these the correlation between the anterior and posterior breadths of the dental arches is so high, it exceeds 0.7 when corrected for age, in both boys and girls at ages 8-14 years, that it may be accepted with complete confidence that a definite association between the two variables would be found if the necessary computations were made. While it must be accepted without question that a definite association exists between the absolute breadths, zygomatic and the dental arch at 6|6 and 4|4 the coefficients in Table 11 for the two variables, breadth of the dental arch at 6|6 and the upper facial index(100 N to U Incis/Zyg B), show quite definitely that there is no correlation whatever between these facial characters in either boys or girls from 8-14 years. There is thus no apparent association between a relatively broad face (height in relation to breadth) and a wide dental arch. From observations on prehistoric English skulls, Sir Arthur Keith (1924) is convinced that in a considerable proportion of the modern population of Britain, there is a tendency for the face to become longer and narrower and that this tendency is directly related to narrowing and arching of the palate. In this connection it is of interest to note that while there is, in a very large group of modern children at ages 8-14 years a very slight but significant tendency for a relatively narrow face (as measured by the upper facial index) to be associated with a relatively high palate, the coefficients in boys and girls are 0.15 and 0.15 respectively when corrected for age and are more than twice their standard errors, there is no appreciable tendency for a relatively broad face to be associated with a wide dental arch (at 6|6). Attempts have been made by various authors including Campion (1906), Pont (1907) and Williams (1917) to determine the breadth of the dental arch by ascertaining certain relationships between the size of the teeth and the size of the arch. Pont's premolar index (100 sum of the incisor widths/distance between premolars) has not been calculated but the width of the upper central incisor has been correlated with the internal and external breadths of the dental arch at 4|4 with the following result:

	Width of upper C.Incis and internal breadth of arch at 4|4 r		Width of upper C.Incis and external breadth of arch at 4|4 r
Normal boys (8-14)	.339±.060 (222)	Special group of boys (10-11)	.404±.097 (74)
Normal girls (8-14)	.347±.065 (182)		

No correction is necessary to eliminate the influence of age in determining the size of the correlations given above as the width of the incisor does not change with age. Quite an appreciable association thus appears to exist between the width of the upper central incisor and the width of the arch and the correlation seems to be of the same order whatever width, external or internal, is taken.

As shown by the coefficients in Table 11 the correlations between the radial measurements T A to N, T A to U I G M and U I I M respectively are about 0. 6 in normal boys and 0.7 in normal girls at ages 8-14 years. Both these corresponding coefficients are approximately 0.7 in children at ages 2-15 years. These values appear to be higher than the corresponding coefficients between the distances T A to N and T A to M P Which is approximately 0.4 in boys and 0.6 in girls at ages 8-14 and 0.5 in children at ages 2-5. The variable development of the region of the chin which is included in the measurement T A to M P might have been suggested as one of the determining factors in producing the less close association between T A to N and T A to M P than between T A to N and T A to U I I M which is clearly shown in the group of boys at ages 8-14 years and evident but less in degree in the group of normal girls at ages 8-14 years, had not the divergence in association been greater in the group of children aged 2-5 years than in the girls at ages 8-14. According to Bolk in his paper on "The Chin Problem" the chin is not developed till the child reaches the age of six years.

There is a slight positive association between the respective measurements T A to N, T A to U I I M and T A to M P and the upper facial index, indicative of a slight tendency for longer radial measurements to accompany a relatively narrow upper face.

In Table 11 are also given, the correlation coefficients found between certain pairs of facial characters in the series of 100 unselected boys in the age group 9-10 years. The values of the coefficients will be seen to be in the majority of the instances tabulated in close agreement with the corresponding coefficients in the longer series of selected boys at the ages 8-14 years. This general accordance in degree of association exhibited between the respective pairs of characters is important as it seems to indicate that the coefficients for the selected series may be accepted as truly representative of the relationship between the characters in the general population of children at the ages under investigation.

Summary and Conclusions.

The present paper is based on records of measurements of numerous characters of the face including the jaws in a series of approximately 1400 children comprising (a) 600 boys and 600 girls attending London schools at ages 8-14 years who were distributed evenly over the age interval and who were essentially selected because their teeth exhibited the anatomically correct or ideal type of occlusion, (b) 100 boys at ages 9-10 who were taken at random from the general population of boys of this age and 100 children varying in age from 2 to 5 years distributed evenly over the age period whose measurements were taken in a Children's Home.

The primary object of the investigation was to establish standards of normality or norms for the different facial characters with the object of facilitating the study of abnormal conditions of the face and jaws. The mean values of the numerous facial characters with their standard errors and the standard deviations or variability as well as the size of the frequency distributions in each case were tabulated for yearly age groups and for 5 centimetre stature groups. Of the many graphs which have been drawn six examples are submitted as illustrative of the type of growth exhibited by the selected characters as age increases from 8 to 14 years. The various methods of testing whether the measurement of a particular facial character in a child diverges to such a degree from the normal that it should be regarded as probably abnormal and not such a measurement as would arise by chance are described and the reasons for the definite preference expressed for a regression equation expressing the measurement of the facial character in terms of age, stature and body weight for the purpose of prediction are explained. Equations are tabulated for each of the separate groups, children aged 2-5, boys aged 8-14 and girls aged 8-14 expressing the facial characters which appear in profile in terms of age, stature and body weight. The errors of prediction in using the equations are also tabulated. A comparison of the mean measurements of the facial characters in the unselected group of boys at ages 9-10 and the group of normal boys at the same age suggests that the anatomically correct, or ideal type of occlusion may be a concomitant of a face which is below the average in general size.

Attention is concentrated on the type of growth exhibited by certain measurements of the face including the jaws. AS the characters are so numerous it is impossible to refer to them all in detail. The figures for the mean measurements of the length of the dental arch at the successive ages supply ample confirmation of the observations of John Hunter, Tomes and Bolk that after complete eruption of the milk teeth the alveolar arch of the human jaw in the region previously occupied by them does not grow any more. As regards the breadth of the dental arches, however, there is a definite increase after 4 years of age; the dental arch becomes part of a wider curve which increases with age as has been demonstrated already by many observers. It is shown that if a suitable adjustment is made for difference of mode of measurement employed the mean transverse measurements of the dental arch in the region of the deciduous molars in American children at successive ages from 2-9years and the mean measurements of Franke's "middle breadth of the alveolar arch" in the region of the first permanent molar in skulls at different ages up to 14 years both show with age a type of growth almost identical with that shown in the breadth of the dental arches in London school children. The interrelationships of the facial characters and their degree of association with age, stature and body weight are shown in six tables of correlation coefficients of zero, first and second orders and a large number of correlation ratios. Amongst many interesting associations that are demonstrated by the coefficients is the fact that a very definite and sensible association exists between the zygomatic breadth and the breadth of the dental arches although such a relationship has been denied by Korkhaus, Linder and Harth, Williams and other observers.

It is shown that while there is in a very large group of modern children at ages 8-14, a very slight but significant tendency for a relatively narrow face to be associated with a relatively higher palate there is no appreciable tendency for a relatively narrow face to be associated with a narrow dental arch at 6 6 .

Comparison of the corresponding coefficients showing the relationship between pairs of characters in the two groups unselected boys at ages 9-10 and selected boys (selected because of the presence of the ideal type of occlusion) shows a very close concordance in the values. This seems to indicate that the coefficients for the selected series may be accepted with some degree of confidence as truly representative of the relationship between the characters in the "universe" of children at the ages under review.

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Tables associated with Thesis.

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TABLE I.

Showing the Mean Values and Variability of the Several Facial Characters at the different ages from 2-4 years.

Males.

Age group (in years)	Sex	T.A. to N.	T.A. to U.I.G.M.	T.A. to U.I.I.M.	T.A. to L.I.G.M.	T.A to M.P.
	M	78.50±0.44*	75.03±0.59	76.11±0.65	73.00±0.85	82.18±0.86
		1.71	2.27	2.43	3.17	3.21
		15	15	14	14	14
2-	F	77.03±0.55	75.81±0.53	76.50±0.64	74.50±0.79	84.44±0.92
		2.20	2.13	2.54	3.14	3.67
		16	16	16	16	16
	M	77.74±0.38	75.44±0.40	76.32±0.46	73.85±0.59	83.38±0.67
	&	2.11	2.23	2.50	3.25	3.64
	F	31	31	30	30	30
	M	80.34±0.79	78.53±0.55	79.38±0.57	76.84±0.62	86.78±0.65
		3.16	2.18	2.30	2.48	2.61
		16	16	16	16	16
3-	F	79.13±0.86	76.81±1.17	77.84±1.08	75.80±1.02	85.22±1.22
		3.45	4.68	4.31	3.96	4.87
		16	16	16	15	16
	M	79.73±0.59	77.67±0.66	78.61±0.63	76.34±0.60	86.00±0.70
	&	3.36	3.75	3.54	3.32	3.98
	F	32	32	32	31	32
	M	81.61±0.79	79.20±1.08	80.42±1.03	78.72±1.12	88.89±1.28
		3.37	4.59	4.37	4.77	5.42
		18	18	18	18	18
4-5	F	79.69±0.70	78.85±1.07	80.04±1.07	79.12±1.10	90.15±0.87
		2.52	3.86	3.84	3.98	3.13
		13	13	13	13	13
	M	80.81±0.57	79.05±0.77	80.26±0.75	78.89±0.80	89.42±0.83
	&	3.19	4.30	4.16	4.46	4.64
	F	31	31	31	31	31

* The tables are all arranged in a similar manner. They show in sequence the mean value of the character and its standard error, the standard deviation or variability and the number of observations on which each average is based. The standard error has not been converted into the probable error by multiplying by 0.67445 or approximately 2/3. In accordance with the usual convention, a difference in mean value may be considered to be statistically significant or sensible if it exceeds twice its standard error (i.e. three times its probable error). The coefficients of variation or percentage variabilities of the characters have not been tabulated but can easily be computed from the formula: c. of v. = 100 standard deviation/mean.

TABLE I
(contd)

Age group (in years)	Sex	Pal Ht.	Zyg. B. of face.	Bigon. B. of face.	N. to S.N.P.	N. to U. Incis.
	M	13.55±0.50	111.35±0.69	84.27±0.63	33.94±0.56	52.94±0.74
		1.59	2.83	2.60	2.29	3.04
		10	17	17	17	17
2-	F	13.12±0.32	109.06±1.24	84.24±0.95	31.76±0.54	50.97±0.76
		1.15	5.11	3.90	2.22	3.14
		13	17	17	17	17
	M	13.31±0.29	110.21±0.74	84.25±0.57	32.85±0.43	51.96±0.56
	&	1.38	4.29	3.31	2.51	3.24
	F	23	34	34	34	34
	M	14.35±0.25	110.32±0.87	86.68±0.88	35.29±0.48	56.00±0.47
		1.03	3.60	3.65	1.99	1.93
		17	17	17	17	17
3-	F	14.82±0.43	110.94±1.15	85.03±1.25	34.47±0.57	54.47±0.52
		1.76	4.72	5.15	2.34	2.13
		17	17	17	17	17
	M	14.59±0.25	110.63±0.72	85.85±0.78	34.88±0.38	55.24±0.37
	&	1.46	4.21	4.54	2.21	2.17
	F	34	34	34	34	34
	M	15.36±0.29	115.06±0.70	88.28±0.72	37.03±0.48	58.58±0.47
		1.25	2.95	3.04	2.02	1.97
		18	18	18	18	18
4-5	F	14.50±0.32	110.35±1.13	86.12±0.92	35.46±0.64	56.27±0.63
		1.12	4.06	3.31	2.29	2.27
		12	13	13	13	13
	M	15.02±0.23	113.08±0.75	87.37±0.60	36.37±0.41	57.61±0.43
	&	1.27	4.17	3.33	2.27	2.39
	F	30	31	31	31	31

TABLE I
(contd)

Age group (in years)	Sex	N. to 6 6	N. to S.M.P.	L. Incis. to S.M.P.	L. Mol. to L.B.M.	L.U.A.
	M	56.37±0.73 2.83 15	83.07±1.17 4.37 14	29.38±0.46 1.89 17	25.10±0.39 1.54 16	28.46±0.28 0.97 12
2-	F.	53.75± 0.77 2.88 14	79.32±1.13 4.64 17	29.02±0.38 1.57 17	25.27±0.38 1.55 17	27.96±0.38 1.37 13
	M & F	55.10±0.58 3.14 29	81.02±0.88 4.89 31	29.20±0.30 1.75 34	25.10±0.27 1.55 33	28.20±0.24 1.22 25
	M	58.15±0.43 1.77 17	85.68±0.58 2.38 17	30.81±0.31 1.29 17	26.22±0.31 1.28 17	28.29±0.37 1.51 17
3-	F	56.85±0.58 2.37 17	83.82±0.78 3.21 17	30.12±0.43 1.75 17	25.79±0.37 1.50 17	28.06±0.37 1.51 17
	M & F	57.50±0.38 2.19 34	84.75±0.51 2.98 34	30.46±0.27 1.58 34	26.00±0.24 1.41 34	28.18±0.26 1.51 34
	M	61.22±0.61 2.59 18	89.61±1.02 4.31 18	32.13±0.51 2.17 18	27.84±0.39 1.67 18	28.56±0.40 1.70 18
4-5	F	58.46±0.71 2.55 13	87.12±0.82 2.95 13	31.13±0.38 1.38 13	27.39±0.41 1.49 13	27.71±0.41 1.41 12
	M & F	60.06±0.52 2.91 31	88.56±0.72 3.99 31	31.71±0.35 1.94 31	27.65±0.29 1.61 31	28.22±0.30 1.64 30

TABLE I
(contd)

Age group (in years)	Sex	L.L.A.	B.at $\underline{D\ \ D}$	B.at $\overline{D\ \ D}$	Upper facial index *	Total facial index †
2-	M	24.79±0.33 1.25 14	39.94±0.42 1.74 17	36.25±0.26 1.05 17	47.55±0.71 2.90 17	74.29±1.25 4.69 14
	F	24.88±0.33 1.18 13	39.55±0.43 1.77 17	35.53±0.43 1.75 17	46.84±0.83 3.41 17	72.82±1.07 4.42 17
	M & F	24.83±0.24 1.22 27	39.74±0.30 1.77 34	35.89±0.26 1.49 34	47.19±0.55 3.19 34	73.48±0.83 4.60 31
3-	M	24.85±0.27 1.12 17	40.61±0.39 1.56 16	36.58±0.34 1.35 16	50.81±0.54 2.23 17	77.71±0.65 2.66 17
	F	24.41±0.34 1.39 17	39.30±0.29 1.19 17	35.31±0.30 1.20 16	49.18±0.66 2.73 17	75.63±0.77 3.17 17
	M & F	24.63±0.22 1.28 34	39.93±0.27 1.53 33	35.94±0.25 1.43 32	49.99±0.45 2.62 34	76.67±0.53 3.10 34
4-5	M	24.67±0.33 1.41 18	40.63±0.52 2.21 18	36.44±0.49 1.95 16	50.93±0.38 1.61 18	77.92±0.91 3.87 18
	F	24.19±0.32 1.17 13	39.43±0.45 1.63 13	34.97±0.35 1.26 13	51.06±0.75 2.71 13	79.04±0.97 3.52 13
	M & F	24.47±0.24 1.34 31	40.13±0.37 2.07 31	35.78±0.34 1.83 29	50.99±0.39 2.14 31	78.39±0.68 3.77 31

* (100 N. to U.Incis/Zyg B.)

† (100 N. to S.M.P./Zyg B.)

TABLE I
(contd)

Age group (in years)	Sex	Fac. Prop. Index *	Stature (cm)	Body weight (kgm)
	M	41.30±0.73	87.44±0.99	13.01±0.21
		2.71	4.08	0.87
		14	17	17
2-	F	40.04±0.38	89.39±0.85	13.21±0.44
		1.57	3.51	1.80
		17	17	17
	M	40.61±0.40	88.41±0.67	13.11±0.24
	&	2.25	3.93	1.42
	F	31	34	34
	M	41.22±0.58	94.25±0.96	14.11±0.38
		2.38	3.94	1.55
		17	17	17
3-	F	41.14±0.60	95.23±1.59	14.17±0.40
		2.49	6.54	1.64
		17	17	17
	M	41.18±0.42	94.74±0.93	14.14±0.27
	&	2.44	5.42	1.59
	F	34	34	34
	M	41.37±0.55	100.82±1.19	16.37±0.46
		2.34	5.06	1.95
		18	18	18
4-5	F	40.69±0.54	101.27±0.96	16.48±0.64
		1.96	3.47	2.32
		13	13	13
		41.09±0.40	101.01±0.80	16.42±0.38
		2.22	4.47	2.11
		31	31	31

* (100 N. to S.N.P./N.to S.M.P.)

TABLE 2.

Showing the Mean Values and Variability of the Several Facial Characters in Boys and Girls at the different ages from 8-14 years.

Males.

Age group.	T.A. to N.	T.A. to U.I.G.M.	T.A. to U.I.I.M.	T.A. to L.I.G.M.	T.A. to M.P.
8-	86.20±0.40	85.64±0.47	87.08±0.47	85.75±0.47	97.59±0.51
	3.50	4.08	4.07	4.07	4.43
	75	75	75	75	75
9-	88.00±0.43	88.28±0.48	90.47±0.51	88.67±0.50	101.19±0.52
	3.62	4.05	4.34	4.27	4.42
	72	72	72	72	72
10-	88.99±0.46	88.65±0.49	90.92±0.53	89.37±0.48	101.92±0.56
	3.50	3.74	4.05	3.65	4.27
	58	58	58	58	58
11-	89.33±0.48	89.44±0.57	91.56±0.56	90.13±0.54	103.02±0.48
	3.43	4.10	4.02	3.90	4.17
	52	52	52	52	52
12-	90.72±0.43	91.28±0.52	92.95±0.53	91.48±0.52	104.95±0.61
	3.36	3.99	4.10	4.02	4.72
	60	60	60	60	60
13-14	92.22±0.74	92.78±0.96	94.32±0.92	93.58±0.96	108.82±1.05
	3.70	4.79	4.62	4.82	5.27
	25	25	25	25	25

Females.

Age group.	T.A. to N.	T.A. to U.I.G.M.	T.A. to U.I.I.M.	T.A. to L.I.G.M.	T.A. to M.P.
8-	84.88±0.36	84.13±0.42	85.65±0.43	84.50±0.40	96.25±0.51
	3.24	3.74	3.86	3.55	4.53
	80	80	80	80	80
9-	84.60±0.46	84.98±0.50	87.18±0.51	85.65±0.47	98.03±0.53
	4.14	4.49	4.57	4.19	4.75
	80	80	80	80	80
10-	86.47±0.41	86.33±0.49	88.39±0.46	86.89±0.46	99.61±0.46
	3.50	4.12	3.91	3.87	3.91
	72	72	72	72	72
11-	87.75±0.47	88.17±0.60	89.81±0.59	88.53±0.57	101.54±0.63
	3.86	4.92	4.80	4.64	5.14
	67	67	67	67	67
12-	88.99±0.47	89.36±0.46	91.36±0.47	89.72±0.45	103.54±0.61
	3.81	3.75	3.80	3.68	4.96
	66	66	66	66	66
13-14	90.06±0.54	90.81±0.64	92.81±0.68	91.99±0.68	107.35±0.82
	3.89	4.56	4.89	4.86	5.82
	51	51	51	51	50

TABLE 2
(contd)

Males.

Age group.	Pal. Ht.	Zyg. B.	Bigon. B.	N.to S.N.P.	N.to U.Incis.
8-	15.88±0.14	119.99±0.41	96.18±0.41	41.38±0.36	65.64±0.38
	1.31	3.94	3.93	3.45	3.60
	92	92	92	92	92
9-	16.41±0.14	121.44±0.40	97.91±0.43	42.44±0.40	67.28±0.41
	1.37	3.83	4.11	3.81	3.90
	90	90	90	90	90
10-	17.54±0.16	122.70±0.47	97.80±0.38	42.91±0.30	67.98±0.35
	1.52	4.34	3.53	2.77	3.20
	86	86	86	86	86
11-	17.56±0.14	123.71±0.44	99.30±0.41	43.55±0.30	69.38±0.36
	1.44	4.40	4.14	3.07	3.68
	102	102	102	102	102
12-	18.35±0.16	125.55±0.39	100.54±0.43	44.43±0.34	69.89±0.40
	1.62	3.88	4.28	3.40	4.01
	99	99	99	99	99
13-14	18.67±0.19	125.73±0.48	100.17±0.52	44.95±0.39	70.86±0.46
	1.88	4.82	5.17	3.89	4.57
	99	99	99	99	99

Females.

Age group.	Pal. Ht.	Zyg. B.	Bigon. B.	N.to S.N.P.	N.to U.Incis.
8-	15.40±0.15	117.68±0.41	94.02±0.40	40.70±0.32	63.84±0.41
	1.39	3.80	3.72	3.01	3.84
	87	88	88	88	88
9-	16.04±0.14	119.10±0.39	94.89±0.36	41.25±0.30	64.34±0.39
	1.45	4.03	3.72	3.03	3.96
	105	105	105	105	105
10-	16.31±0.15	120.06±0.42	95.92±0.37	42.09±0.32	65.56±0.36
	1.47	4.11	3.63	3.19	3.52
	97	97	97	97	97
11-	17.20±0.15	121.73±0.52	96.63±0.45	42.81±0.29	67.22±0.37
	1.49	5.16	4.46	2.89	3.68
	98	98	98	98	98
12-	18.09±0.14	123.55±0.44	98.24±0.42	43.18±0.30	67.44±0.36
	1.37	4.41	4.28	3.01	3.59
	102	102	102	102	102
13-14	18.76±0.17	125.57±0.42	99.35±0.47	44.77±0.33	69.63±0.36
	1.70	4.20	4.71	3.26	3.57
	101	101	101	101	101

TABLE 2
(contd)

Males.

Age group.	N. to S.M.P.	L. Incis to S.M.P.	L. Mol. to L.B.M.	L.U.A.	L.L.A.
8-	98.40±0.52	35.84±0.23	29.53±0.22	39.02±0.25	34.93±0.23
	4.96	2.22	2.07	1.86	1.70
	92	91	91	56	56
9-	100.79±0.57	36.87±0.24	30.29±0.21	39.63±0.30	35.20±0.25
	5.36	2.25	2.02	2.21	1.87
	90	90	89	55	55
10-	101.45±0.45	36.95±0.23	30.68±0.17	38.82±0.30	34.48±0.25
	4.15	2.13	1.58	2.05	1.70
	86	84	84	47	47
11-	103.59±0.48	38.00±0.23	31.81±0.20	38.01±0.49	33.74±0.54
	4.81	2.30	2.01	2.00	2.24
	102	102	102	17	17
12-	103.23±0.52	38.83±0.23	33.08±0.19	38.83±0.66	32.83±0.68
	5.14	2.29	1.92	2.28	2.36
	99	99	99	12	12
13-14	106.83±0.62	39.32±0.24	33.64±0.23	36.94±0.66	32.33±0.58
	6.18	2.40	2.27	1.98	1.75
	99	99	99	9	9

Females

Age group.	N. to S.M.P.	L. Incis to S.M.P.	L. Mol. to L.B.M.	L.U.A.	L.L.A.
8-	96.11±0.58	34.85±0.21	28.70±0.21	38.39±0.27	34.25±0.21
	5.41	1.97	2.01	2.03	1.60
	88	88	88	56	56
9-	97.11±0.45	35.36±0.20	29.36±0.18	38.80±0.26	34.31±0.20
	4.61	2.04	1.83	2.07	1.58
	105	105	105	65	65
10-	98.28±0.44	35.92±0.20	30.15±0.18	38.89±0.26	33.93±0.27
	4.30	1.93	1.78	1.92	2.05
	97	97	97	56	56
11-	101.22±0.51	37.05±0.23	31.69±0.21	37.70±0.40	32.73±0.40
	5.00	2.28	2.06	2.13	2.09
	98	98	98	28	28
12-	101.81±0.48	37.44±0.24	32.31±0.22	38.11±0.48	32.22±0.43
	4.80	2.42	2.20	2.03	1.84
	102	102	102	18	18
13-14	105.38±0.51	38.52±0.23	33.71±0.21	36.68±0.57	31.32.0±57
	5.14	2.33	2.11	1.90	1.89
	101	101	101	11	11

TABLE 2
(contd)

Males.

Age group.	N. to $\underline{6 \quad 6}$	B. at D. or $\underline{4 \quad 4}$	B. at $\underline{6 \quad 6}$	B. at D. or $\overline{4 \quad 4}$	B. at $\overline{6 \quad 6}$
8-	68.40±0.33	43.41±0.22	55.53±0.27	38.07±0.21	53.58±0.26
	3.16	1.89	2.37	1.84	2.27
	92	76	76	76	
9-	69.68±0.35	44.11±0.25	56.00±0.25	38.97±0.22	53.88±0.24
	3.31	2.13	2.09	1.84	2.00
	90	71	72	68	72
10-	70.52±0.32	44.46±0.27	55.98±0.28	38.55±0.24	53.75±0.26
	2.99	2.04	2.12	1.83	1.92
	86	56	56	56	56
11-	72.26±0.34	45.38±0.25	56.79±0.28	40.04±0.22	54.77±0.26
	3.47	1.79	2.02	1.59	1.88
	102	52	52	52	52
12-	72.81±0.39	45.87±0.29	57.35±0.33	40.08±0.24	54.97±0.27
	3.84	2.22	2.52	1.85	1.06
	99	60	60	60	60
13-14	73.50±0.42	45.73±0.41	56.66±0.53	40.29±0.48	54.42±0.54
	4.14	2.06	2.66	2.38	2.72
	99	25	25	25	25

Females.

Age group.	N. to $\underline{6 \quad 6}$	B. at D. or $\underline{4 \quad 4}$	B. at $\underline{6 \quad 6}$	B. at D. or $\overline{4 \quad 4}$	B. at $\overline{6 \quad 6}$
8-	67.00±0.41	42.09±0.21	53.61±0.22	37.12±0.19	52.09±0.25
	3.82	1.86	2.00	1.69	2.21
	88	80	80	79	80
9-	67.52±0.30	42.74±0.19	53.76±0.22	37.46±0.20	52.05±0.20
	3.10	1.71	1.99	1.72	1.83
	104	80	80	77	80
10-	68.24±0.31	43.42±0.22	54.63±0.25	38.27±0.19	52.71±0.25
	3.07	1.84	2.11	1.62	2.12
	97	72	72	70	72
11-	69.99±0.34	44.05±0.26	55.01±0.26	38.98±0.23	52.91±0.21
	3.36	2.17	2.14	1.84	1.71
	98	67	67	66	66
12-	70.63±0.31	44.55±0.25	55.47±0.26	39.05±0.19	53.36±0.23
	3.10	2.07	2.09	1.54	1.87
	102	66	66	66	66
13-14	72.40±0.35	44.83±0.29	55.99±0.29	39.34±0.25	53.66±0.29
	3.55	2.09	2.04	1.80	2.08
	101	51	51	51	51

TABLE 2
(contd)

Males

Age group.	Upper Facial Index	Total Facial Index	Fac. Prop. Index	Stature (cm)	Body weight (kgm)
8-	54.73±0.28	82.04±0.41	42.11±0.30	123.95±0.71	24.84±0.28
	2.64	3.89	2.91	6.66	2.62
	92	92	92	88	88
9-	55.47±0.31	82.93±0.44	42.16±0.28	128.67±0.68	27.80±0.34
	2.93	4.14	2.66	6.35	3.21
	90	90	90	88	88
10-	55.58±0.30	82.83±0.45	42.36±0.23	133.90±0.78	30.00±0.37
	2.76	4.17	2.18	7.17	3.43
	86	86	86	85	85
11-	56.45±0.27	83.78±0.36	42.16±0.23	137.05±0.72	31.86±0.37
	2.76	3.65	2.33	7.18	3.73
	101	102	102	100	99
12-	55.88±0.32	83.87±0.42	42.19±0.25	142.30±0.68	36.61±0.49
	3.23	4.19	2.49	6.72	4.84
	99	99	99	98	98
13-14	56.32±0.31	85.18±0.42	42.21±0.27	145.93±0.79	37.89±0.68
	3.06	4.18	2.65	7.69	6.51
	99	99	99	95	93

Females

Age group.	Upper Facial Index	Total Facial Index	Fac. Prop. Index	Stature (cm)	Body weight (kgm)
8-	54.32±0.30	81.84±0.42	42.35±0.25	123.33±0.65	24.52±0.38
	2.83	3.98	2.38	6.05	3.54
	88	88	88	88	88
9-	54.15±0.29	81.79±0.38	42.40±0.21	127.68±0.66	26.38±0.34
	3.01	3.85	2.16	6.76	3.43
	105	105	105	104	104
10-	54.78±0.26	82.00±0.36	42.86±0.27	131.83±0.85	27.96±0.38
	2.58	3.52	2.62	8.26	3.74
	97	97	97	95	95
11-	55.35±0.30	83.20±0.45	42.35±0.23	136.27±0.83	32.00±0.56
	2.98	4.41	2.24	8.15	5.54
	98	98	98	97	97
12-	54.62±0.33	82.47±0.45	42.37±0.22	143.48±0.70	36.27±0.49
	3.36	4.53	2.25	7.05	4.96
	103	103	103	102	103
13-14	55.56±0.25	84.12±0.38	42.62±0.27	149.55±0.77	41.29±0.65
	2.54	3.83	2.71	7.63	6.43
	101	101	101	98	98

For Table 3 substitute

Table 15, page 54

Medical Research Council Special Report No. 171, 1932.

"Facial Growth in Children

with special reference to Dentition".

This note is inserted at the request of

Dr. Matthew Young.

October, 1935.

T. C. Nash.

Professor of Anatomy.

TABLE 3

Showing a Comparison of the Mean Values and Variability of the Facial Characters in two series of Selected and Unselected Boys at ages 9-10 years.

Groups.	T.A.to N.	T.A.to U.I.G.M.	T.A.to U.I.I.M.	T.A.to L.I.G.M.	T.A.to M.P.
Selected boys	87.07±0.34 3.36 100	85.87±0.43 4.26 100	87.89±0.43 4.32 100	86.07±0.44 4.36 100	99.27±0.44 4.37 100
Un-selected boys.	88.00±0.43 3.62 72	88.28±0.48 4.05 72	90.47±0.51 4.34 72	88.67±0.50 4.27 72	101.19±0.52 4.42 72

Groups.	Pal. Ht.	Zyg. B.	Bigon. B.	N.to S.N.P	N.to U.Incis.
Selected boys.	16.92±0.15 1.45 97	120.35±0.38 3.83 100	96.79±0.39 3.85 100	42.81±0.30 2.99 100	66.59±0.35 3.45 100
Un-selected boys	16.41±0.13 1.37 90	121.44±0.40 3.83 90	97.01±0.43 4.11 90	42.44±0.40 3.81 90	67.28±0.41 3.90 90

Groups.	N.to 6 6	N.to S.M.P.	L,Incis to S.M.P.	L.Mol. to L.B.M.	L.U.A.
Selected boys	68.38±0.29 2.80 97	99.49±0.48 4.78 100	36.42±0.23 2.23 98	29.78±0.18 1.80 95	38.21±0.27 2.70 97
Un-selected boys	69.68±0.35 3.31 90	100.79±0.57 5.36 90	36.87±0.24 2.25 90	30.29±0.21 2.02 89	39.63±0.30 2.21 55

Groups.	L.L.A.	B.at D. or 4 4	B.at 6 6	B.at D. or 4 4	B.at 6 6
Selected boys	33.46±0.20 1.94 96	43.04±0.35 2.43 48	53.87±0.27 2.65 95	38.18±0.42 2.11 25	52.81±0.25 2.36 87
Un-selected boys	35.20±0.25 1.87 55	44.11±0.25 2.13 71	56.00±0.25 2.09 72	38.97±0.22 1.84 68	53.88±0.24 2.00 72

Groups.	Upper Facial Index	Total Facial Index	Fac. Prop. Index	Stature	Body Weight
Selected boys	55.32±0.28 2.79 100	82.76±0.38 3.83 100	43.08±0.28 2.80 100	129.05±0.60 5.98 100	27.15±0.36 3.62 100
Un-selected boys	55.47±0.31 2.93 90	82.93±0.44 4.14 90	42.16±0.28 2.66 90	128.67±0.68 6.35 88	27.80±0.34 3.21 88

Groups.	Age
Selected boys	9 y. 6.5±0.34 3.39 100
Un-selected boys	9 y. 5.6±0.37 3.51 90

TABLE 4

Showing the Mean Values and Variability of the Several Facial Characters in Boys graded according to Full Stature.

Height groups (cm)	T.A.to N.	T.A.to U.I.G.M.	T.A.to U.I.I.M.	T.A.to L.I.G.M.	T.A.to M.P.
110-	83.64	83.29	84.86	83.36	94.93
	7	7	7	7	7
115-	85.58±0.67	84.48±0.95	85.45±0.86	84.73±0.95	96.03±0.94
	3.01	4.27	3.86	4.24	4.21
	20	20	20	20	20
120-	86.43±0.61	86.53±0.62	88.41±0.64	86.51±0.61	98.54±0.72
	3.70	3.78	3.87	3.70	4.35
	37	37	37	37	37
125-	87.99±0.42	87.75±0.49	89.66±0.52	87.99±0.50	99.78±0.54
	3.47	4.06	4.28	4.15	4.47
	68	68	68	68	68
130-	88.22±0.42	88.48±0.46	90.58±0.51	89.02±0.46	102.18±0.53
	3.27	3.60	3.92	3.60	4.07
	60	60	60	60	60
135-	89.54±0.43	89.89±0.49	92.07±0.48	90.59±0.48	103.15±0.48
	3.26	3.72	3.59	3.63	3.65
	57	57	57	57	57
140-	90.86±0.40	91.99±0.65	93.68±0.59	92.26±0.60	106.05±0.67
	2.52	4.04	3.69	3.74	4.20
	39	39	39	39	39
145-	90.27±0.68	91.17±0.97	93.08±0.97	91.44±0.89	106.29±1.04
	3.49	4.96	4.95	4.55	5.32
	26	26	26	26	26
150-	93.35±1.08	93.12±1.17	95.00±1.22	94.19±1.26	108.42±1.42
	3.91	4.22	4.39	4.53	5.12
	13	13	13	13	13
155-	94.00	91.33	92.67	92.00	106.33
	3	3	3	3	3
160-	91.00	86.50	87.50	86.25	106.50
	2	2	2	2	2

TABLE 4
(contd)

Height groups (cm)	Pal. Ht.	Zyg. B.	Bigon.B.	N.to S.N.P	N. to U.Incis.
110-	16.00	117.29	94.50	40.43	67.50
	7				
115-	16.15±0.23	118.96±0.53	95.19±0.63	39.83±0.65	63.54±0.69
	1.11	2.60	3.10	3.20	3.38
	24	24	24	24	24
120-	16.06±0.21	119.41±0.54	96.01±0.59	41.43±0.50	65.32±0.54
	1.41	3.67	4.06	3.46	3.73
	47	47	47	47	47
125-	16.28±0.15	120.76±0.39	96.76±0.41	42.38±0.30	66.61±0.33
	1.46	3.68	3.93	2.87	3.13
	91	91	91	91	91
130-	17.13±0.16	122.27±0.44	97.71±0.39	42.82±0.35	68.06±0.36
	1.51	4.18	3.68	3.33	3.38
	89	89	89	89	89
135-	17.56±0.15	124.06±0.38	99.37±0.40	43.66±0.30	68.95±0.31
	1.58	4.10	4.29	3.27	3.38
	117	117	117	117	117
140-	18.20±0.18	125.33±0.45	100.07±0.49	43.70±0.41	69.96±0.48
	1.61	3.88	4.30	3.59	4.16
	76	76	76	76	76
145-	18.92±0.19	126.45±0.45	101.01±0.51	44.97±0.41	71.12±0.55
	1.37	3.27	3.74	3.05	4.03
	54	54	54	54	54
150-	10.10±0.29	127.10±0.91	102.24±0.84	46.43±0.49	72.44±0.64
	1.62	5.06	4.68	2.68	3.57
	31	31	31	30	31
155-	19.56±0.28	128.94±1.02	102.72±1.26	47.50±1.14	73.39±1.38
	0.83	3.07	3.77	3.42	4.13
	9	9	9	9	9
160-	18.86	125.57	101.36	45.71	72.07
	7	7	7	7	7
165-	19.50	128.00	104.50	46.75	68.75
	2	2	2	2	2

TABLE 4
(contd)

Height groups (cm)	N. to $\underline{6\quad 6}$	N. to S.M.P.	L. Incis. to L.B.M.	L. Mol. to L.B.M.	B. at D. or $\underline{4\quad 4}$
110-	67.86 7	98.07	35.11	27.74	42.57
115-	66.83±0.62 3.04 24	96.60±1.18 5.76 24	35.71±0.62 3.06 24	28.93±0.52 2.56 24	43.24±0.41 1.82 20
120-	68.45±0.52 3.57 47	98.92±0.74 5.10 47	36.48±0.31 2.09 46	29.80±0.23 1.55 46	43.55±0.33 2.00 37
125-	69.23±0.29 2.80 91	99.83±0.47 4.51 91	36.23±0.22 2.08 90	30.24±0.20 1.87 89	44.06±0.27 2.16 66
130-	70.55±0.30 2.88 89	101.72±0.47 4.41 89	37.15±0.20 1.91 88	30.80±0.18 1.69 88	44.25±0.26 2.00 60
135-	71.78±0.29 3.14 117	102.85±0.43 4.68 117	37.50±0.18 1.99 117	31.46±0.19 2.04 117	45.22±0.23 1.76 57
140-	72.49±0.43 3.77 76	105.41±0.59 5.17 76	39.03±0.28 2.44 76	33.25±0.22 1.88 76	45.70±0.35 2.17 39
145-	73.94±0.47 3.47 54	106.42±0.65 4.80 54	39.35±0.32 2.32 54	33.39±0.25 1.83 54	46.08±0.37 1.86 26
150-	75.32±0.52 2.88 31	108.98±0.90 5.02 31	39.98±0.37 2.08 31	34.49±0.33 1.86 31	45.69±0.72 2.59 13
155-	76.94±1.12 3.35 9	111.44±1.73 5.18 9	40.73±0.70 2.11 9	34.83±0.53 1.58 9	47.13 4
160-	74.79 7	108.79 7	40.94 7	35.11 7	45.00 2
165-	76.00 2	107.50 2	39.25 2	33.85 2	

TABLE 4
(contd)

Height groups (cm)	B.at $\underline{6 \quad 6}$	B.at D. or $\overline{4 \quad 4}$	B.at $\overline{6 \quad 6}$	L.U.A.	L.L.A.
110-	54.93 7	37.43	53.23	38.42	34.67
115-	54.87±0.46 2.05 20	38.03±0.25 1.11 20	53.01±0.49 2.20 20	38.20±0.45 1.75 15	34.27±0.40 1.56 15
120-	55.56±0.35 2.13 37	38.22±0.31 1.85 35	53.39±0.33 2.03 37	39.21±0.36 1.89 28	34.95±0.30 1.57 28
125-	55.75±0.26 2.12 67	38.61±0.25 2.02 66	53.71±0.26 2.11 67	38.93±0.30 2.09 49	34.96±0.24 1.69 49
130-	55.80±0.29 2.21 60	38.57±0.24 1.85 60	53.87±0.26 2.00 60	39.28±0.35 2.21 40	34.66±0.34 2.17 40
135-	57.15±0.28 2.13 57	39.82±0.22 1.67 56	54.78±0.26 1.96 57	39.30±0.29 1.61 30	34.03±0.34 1.85 30
140-	57.17±0.32 2.00 39	40.01±0.30 1.87 39	54.68±0.31 1.93 39	38.15±0.78 2.47 10	33.20±0.46 1.47 10
145-	57.17±0.40 2.02 26	40.32±0.36 1.81 26	54.83±0.37 1.89 26	39.30±0.93 2.95 10	33.80±0.78 2.46 10
150-	57.19±0.85 3.08 13	40.42±0.63 2.27 13	54.70±0.76 2.74 13	-	-
155-	57.88 4	41.30 4	55.90 4	-	-
160-	55.20 2	39.30 2	52.80 2	-	-

TABLE 5

Showing the Mean Values and Variability of the Several Facial Characters in Girls graded according to Full Stature.

Height groups (cm)	T.A.to N.	T.A.to U.I.G.M.	T.A.to U.I.I.M.	T.A.to L.I.G.M.	T.A.to M.P.
110-	80.86 - 7	81.29 - 7	82.71 - 7	82.00 - 7	91.50 - 7
115-	82.08±0.62 3.47 31	81.85±0.54 3.03 31	83.63±0.62 3.43 31	82.65±0.53 2.97 31	92.76±0.54 3.00 31
120-	84.61±0.49 3.10 40	84.33±0.59 3.73 40	86.16±0.62 3.95 40	84.61±0.60 3.80 40	96.00±0.57 3.59 40
125-	85.89±0.34 3.16 87	85.54±0.40 3.74 87	87.34±0.40 3.69 87	85.93±0.39 3.60 87	98.83±0.43 4.03 87
130-	86.34±0.37 3.29 78	85.85±0.49 4.32 78	88.06±0.49 4.32 78	86.44±0.44 3.89 78	99.62±0.44 3.90 78
135-	86.79±0.55 4.06 54	88.42±0.59 4.30 54	90.16±0.61 4.51 54	89.01±0.56 4.10 54	101.82±0.56 4.11 54
140-	88.93±0.58 3.47 36	89.36±0.67 4.00 36	91.31±0.64 3.87 36	89.56±0.59 3.56 36	102.96±0.71 4.28 36
145-	90.15±0.54 3.13 34	90.34±0.60 3.51 34	92.15±0.60 3.52 34	91.00±0.58 3.36 34	105.46±0.80 4.67 34
150-	91.33±0.65 3.20 24	91.98±0.80 3.90 24	94.04±0.83 4.08 24	92.69±0.79 3.88 24	107.67±1.10 5.39 24
155-	91.38±0.79 2.74 12	91.42±0.69 2.40 12	92.79±0.71 2.47 12	91.79±0.91 3.17 12	108.67±1.47 5.09 12
160-	91.25 - 6	92.25 - 6	94.58 - 6	93.58 - 6	110.75 - 6
165-	93.75 - 2	95.50 - 2	07.75 - 2	07.50 - 2	118.00 - 2

TABLE 5
(contd)

Height group (cm)	Pal. Ht.	Zyg. B.	Bigon. B.	N. to S.N.P.	N. to U.Incis.
110-	15.44 - 8	114.25 - 8	93.69 - 8	37.19 - 8	59.44 - 8
115-	15.08±0.20 1.24 37	115.66±0.55 3.33 37	92.32±0.46 2.82 37	40.08±0.46 2.80 37	62.18±0.53 3.21 37
120-	15.47±0.17 1.27 54	117.38±0.47 3.47 54	94.12±0.45 3.33 54	40.53±0.37 2.71 54	63.75±0.41 2.98 54
125-	15.99±0.14 1.43 105	119.01±0.32 3.25 106	95.22±0.34 3.49 106	41.64±0.28 2.84 106	65.35±0.35 3.65 106
130-	16.69±0.14 1.37 103	121.03±0.40 4.02 103	95.79±0.37 3.78 103	42.46±0.26 2.59 103	65.63±0.32 3.22 103
135-	16.94±0.15 1.31 75	121.30±0.49 4.24 75	96.31±0.43 3.72 75	42.43±0.36 3.15 75	66.42±0.39 3.38 75
140-	17.82±0.20 1.56 63	123.21±0.54 4.26 63	97.78±0.58 4.58 63	43.48±0.39 3.13 63	68.23±0.47 3.70 63
145-	18.75±0.17 1.31 60	125.78±0.58 4.46 60	99.12±0.56 4.33 60	43.98±0.39 3.01 60	68.82±0.45 3.45 60
150-	18.91±0.20 1.31 43	126.13±0.48 3.18 43	100.38±0.57 3.72 43	44.97±0.50 3.30 43	70.20±0.55 3.58 43
155-	18.87±0.44 2.10 23	126.83±0.82 3.94 23	101.30±0.92 4.41 23	45.15±0.65 3.11 23	69.91±0.83 4.00 23
160-	18.83±0.47 1.40 9	124.28±2.08 6.24 9	98.56±1.05 3.15 9	42.72±1.08 4.25 9	66.94±1.04 3.13 9
165-	19.33 - 3	132.50 - 3	102.00 - 3	46.17 - 3	70.83 - 3

TABLE 5
(contd)

Height groups (cm)	N.to 6 6	N.to S.M.P.	L.Incis to S.M.P.	L.Mol. to L.B.M.	L.U.A.
110-	63.50 - 8	91.13 - 8	33.79 - 8	27.70 - 8	36.33 - 3
115-	65.58±0.43 2.60 36	93.80±0.64 3.92 37	34.15±0.28 1.68 37	28.00±0.26 1.61 37	37.86±0.44 2.03 21
120-	66.56±0.38 2.76 54	96.19±0.51 3.74 54	35.35±0.24 1.80 54	29.07±0.22 1.62 54	38.27±0.34 1.89 31
125-	68.20±0.34 3.47 106	98.24±0.46 4.71 106	35.70±0.19 1.91 106	29.82±0.18 1.88 106	38.61±0.26 1.99 60
130-	68.97±0.31 3.12 103	99.10±0.43 4.36 103	36.67±0.23 2.29 103	30.47±0.20 2.04 103	38.67±0.31 2.26 53
135-	69.27±0.31 2.65 75	100.11±0.47 4.07 75	36.67±0.25 2.13 75	31.14±0.24 2.06 75	38.84±0.33 1.83 31
140-	70.45±0.42 3.36 63	102.56±0.70 5.56 63	37.60±0.32 2.52 63	32.17±0.26 2.09 63	38.00±0.56 2.18 15
145-	71.82±0.37 2.83 60	103.78±0.57 4.42 60	37.78±0.29 2.28 60	33.03±0.25 1.90 60	38.29 - 7
150-	73.24±0.49 3.22 43	105.95±0.75 4.93 43	38.71±0.30 1.95 43	33.99±0.34 2.25 43	38.00 - 7
155-	72.63±0.77 3.68 23	105.72±1.43 6.84 23	38.74±0.63 3.03 23	34.11±0.43 2.05 23	36.17 - 3
160-	71.00±0.86 2.59 9	101.28±1.50 4.51 9	37.31±0.44 1.31 9	33.30±0.61 1.83 9	-
165-	74.33 - 3	107.17 - 3	39.57 - 3	33.47 - 3	-

TABLE 5
(contd)

Height groups (cm)	L.L.A.	B.at D or 4 4	B.at 6 6	B.at D. or 4 4	B.at 6 6
110-	33.17 - 3	41.26 - 7	51.99 - 7	36.60 - 7	50.87 - 7
115-	33.74±0.33 1.52 21	41.98±0.26 1.43 31	53.29±0.33 1.85 31	36.52±0.30 1.68 31	51.16±0.37 2.07 31
120-	33.95±0.26 1.47 31	42.31±0.31 1.96 40	53.23±0.27 1.70 40	37.14±0.24 1.53 39	51.73±0.24 1.50 40
125-	34.03±0.22 1.73 60	42.88±0.19 1.78 87	53.93±0.21 1.99 87	37.67±0.19 1.70 84	52.59±0.22 2.09 87
130-	33.97±0.33 2.41 53	43.10±0.21 1.90 78	54.63±0.22 1.94 78	38.30±0.17 1.51 75	52.66±0.19 1.70 77
135-	33.82±0.29 1.60 31	44.30±0.28 2.08 54	55.11±0.29 2.11 54	38.69±0.28 2.04 54	52.94±0.31 2.27 54
140-	32.43±0.61 2.37 15	44.21±0.38 2.30 36	55.14±0.37 2.24 36	38.77±0.28 1.65 36	52.83±0.30 1.80 36
145-	31.36 - 7	44.74±0.38 2.21 34	55.86±0.30 1.75 34	39.23±0.29 1.68 34	53.40±0.31 1.79 34
150-	34.07 - 7	45.01±0.39 1.89 24	56.45±0.39 1.91 24	39.66±0.30 1.48 24	54.40±0.33 1.63 24
155-	30.17 - 3	44.76±0.66 2.27 12	55.64±0.63 2.18 12	39.75±0.46 1.58 12	53.46±0.50 1.74 12
160-	-	45.10 - 6	56.28 - 6	40.12 - 6	54.28 - 6
165-	-	45.85 - 2	57.00 - 2	39.85 - 2	54.55 - 2

TABLE. 6

Correlation Coefficients between the several Facial Characters and age, Stature, and Body Weight respectively in children at ages 2 -5 years.

		Age.	Full stature.	Bodyweight.	No. of obs.
TA to N	and	.299±.084	.364±.089	.435±.084	94
TA to UIGM	"	.322±.092	.401±.087	.452±.082	94
TA to UIIM	"	.351±.091	.421±.085	.425±.085	93
TA to LIGM	"	.422±.086	.428±.085	.549±.073	92
TA to MP	"	.484±.079	.613±.065	.646±.060	93
Pal HI	"	.416±.089	.567±.073	.491±.081	87
Zyg B	"	.262±.094	.354±.088	.529±.072	99
BIg B	"	.256±.094	.329±.090	.542±.071	99
I to SNP	"	.543±.071	.594±.065	.488±.077	99
I to U Incis.	"	.641±.059	.656±.057	.515±.074	99
I to <u>616</u>	"	.591±.067	.673±.056	. -	94
I to SMP	"	.612±.064	.694±.053	.640±.060	96
L Incis to SMP.	"	.493±.076	.576±.067	..629±.061	99
LM to LBM	"	.529±.073	.614±.063	-	98
LUA	"	.044±.106	.121±.104	-	89
LLA	"	-.049±.104	-.006±.104	-	92
Rat <u>D|D</u>	"	.064±.101	.005±.101	-	98
Rat $\overline{D|D}$	"	-.028±.103	.004±.103	-	95
T.F.I.	"	.480±.0	-	-	99
A.F.I.	"	.473±.079	-	-	96
A.P.I.	"	.066±.102	-	-	96
Age	"	-	.792±.038	.637±.060	99
Stature	"	-	-	.739±.046	99

TABLE 7

Correlation of facial characters with age in boys and girls at ages 8-14 years.

[Coefficients (r) and Ratios η]

Characters		Boys No. of Obs.	Boys r	Boys η (corrected)	Girls No. of Obs.	Girls r	Girls η (corrected)
TA to N	and age.	343	.462±.043	.480±.042	416	.464±.039	.472±.038
TA to UIGM	" "	343	.466±.042	.493±.041	416	.487±.037	.485±.038
TA to UIIM	" "	343	.455±.043	.492±.041	416	.494±.037	.485±.038
TA to LIGM	" "	343	.483±.041	.504±.040	416	.514±.036	.511±.036
TA to MP	" "	343	.586±.036	.580±.036	415	.591±.032	.600±.031
Pal. Ht.	" "	568	.532±.030	.538±.030	590	.624±.025	.626±.025
Zyg. B	" "	568	.436±.034	.435±.034	591	.521±.030	.517±.030
Bigon. B	" "	568	.317±.038	.323±.038	591	.407±.034	.407±.034
N to SNP	" "	568	.331±.037	.328±.038	591	.399±.035	.401±.035
N to U inc.	" "	568	.412±.035	.411±.035	592	.469±.032	.473±.032
N to 616	" "	568	.457±.033	.455±.033	591	.483±.032	.497±.031
L inc. to SMP	" "	565	.466±.033	.463±.033	592	.502±.031	.501±.031
L Mol. to LBM	" "	565	.595±.027	.598±.027	592	.652±.024	.653±.024
Ext. breadth at 414	"	341	.412±.045	.418±.045	416	.441±.040	.434±.040
Ext. breadth at 616	"	342	.253±.051	.278±.050	416	.375±.042	.364±.043
Ext. breadth at 414	"	338	.375±.047	.395±.046	409	.434±.040	.429±.040
Ext. breadth at 616	"	342	.208±.052	.240±.051	415	.282±.045	.262±.046
Int. breadth at 414	"	218	.108±.067	-	175	-.089±.075	-
Int. breadth at 616	"	218	.248±.064	-	175	.314±.068	-
Int. breadth at 414	"	218	.326±.061	-	175	.298±.069	-
Int. breadth at 616	"	218	.057±.068	-	175	.126±.074	-
UJA	" "	195	-.163±.070	-	234	-.129±.064	-
LJA	" "	196	-.360±.062	-	234	-.368±.057	-
Upper facial index	"	568	.178±.041	.192±.040	592	.149±.040	.191±.040
Total facial index	"	568	.237±.040	.231±.040	592	.185±.040	.215±.039
Ho.prop. index	" "	568	.005±.042	-	592	.014±.041	-

TABLE 8

Correlation of facial characters with stature and bodyweight in boys and girls at ages 8-14 years.

	Boys					Girls				
	Full stature			Bodyweight		Full stature			Bodyweight	
	No.of obs.	r	n (corrected)	Nobof obs.	r	No.of obs.	r	n (corrected)	No.of obs.	r
TA to N and	332	.494±.042	.497±.041	.331	.489±.042	411	.605±.031	.610±.031	411	.611±.031
TA to UIGM	332	.468±.043	. -	.331	.523±.040	411	.593±.032	-	411	.649±.029
TA to UIIM	332	.468±.043	.497±.041	331	.512±.041	411	.588±.032	.589±.032	411	.649±.029
TA to LIGM	332	.480±.042	-	332	.539±.039	411	.617±.031	-	411	.679±.027
TA to MP	332	.601±.035	-	331	.649±.032	410	.709±.025	.708±.025	410	.771±.020
Pal. Ht.	554	.546±.030	.555±.029	-	-	583	.649±.024	.660±.023	584	.680±.022
Zyg. B	554	.549±.030	.555±.029	-	-	584	.637±.025	.645±.024	585	.690±.022
Bigon. B	554	.448±.034	-	-	-	584	.493±.031	-	-	-
N to SNP	554	.408±.035	-	551	.427±.035	584	.424±.034	-	585	.449±.033
N to U inc.	554	.498±.032	.516±.031	551	.536±.030	584	.526±.030	.546±.029	585	.571±.028
N to 616	554	.564±.029	-	-	-	583	.556±.029	-	-	-
N to SMP	554	.554±.030	.556±.029	551	.593±.028	584	.569±.028	.585±.027	585	.639±.024
L inc. to SMP	551	.515±.031	-	548	.553±.030	584	.492±.031	-	585	.597±.027
L Md. to LBM	550	.657±.024	-	-	-	584	.661±.023	-	-	-
Ext.B of arches at 414	331	.412±.046	.411±.046	-	-	411	.437±.040	.434±0040	-	-
Ext.B of arches at 616	332	.306±.050	.319±.049	-	-	411	.447±.040	.444±.040	-	-
Ext B. of arches at 414	328	.398±.047	.403±.046	-	-	404	.476±.039	.466±.039	-	-
Ext.B.of arches at 616	332	.247±.052	.255±.051	-	-	410	.364±.043	.364±.043	-	-
JA	190	.038±.072	-	-	-	221	.043±.066	-	-	-
LA	190	.038±.072	-	-	-	231	-.196±.063	-	-	-
Upper facial ind.	554	.194±.041	-	-	-	585	.121±.041	-	-	-
Total facial ind.	554	.210±.041	-	-	-	584	.127±.041	-	-	-

TABLE 9

Correlation Coefficients of the second order.

Children aged 2 - 5 years.

	Age ē stature and body weight constant.	Stature c̄ age and body weight constant.	Body weight with age & stature constant.	No. of obs.
TA to N and	-.016±.103	.065±.103	.264±.096	94
TA to UIGM "	-.025±.103	.103±.102	.253±.097	94
TA to UIIM "	.009±.104	.133±.102	.184±.100	93
TA to LIGM "	.111±.103	.038±.104	.370±.090	92
TA to MP "	-.054±.103	.242±.098	.366±.090	93
N to SNP "	.138±.099	.249±.094	.074±.100	99
N to U inc. "	.259±.094	.267±.093	.027±.100	99
N to SMP "	.113±.101	.290±.093	.249±.096	96
L inc. to SMP "	.030±.100	.152±.098	.363±.087	99

Boys aged 8 - 14 years.

TA to N "	.097±.054	.113±.054	.106±.054	331
TA to UIGM "	.107±.054	-.012±.055	.229±.052	331
TA to UIIM "	.085±.055	.019±.055	.208±.053	331
TA to LIGM "	.118±.054	-.013±.055	.235±.052	331
TA to MP "	.154±.054	.035±.055	.371±.051	331
N to SNP "	-.006±.043	.100±.042	.166±.041	551
N to U inc. "	.016±.043	.096±.042	.238±.040	551
N to SMP "	.054±.042	.105±.042	.261±.040	551
L inc. to SMP "	.076±.042	.083±.042	.232±.040	551

Girls aged 8 - 14 years.

TA to N "	.069±.049	.179±.048	.203±.047	411
TA to UIGM "	-.012±.049	.036±.049	.328±.044	411
TA to UIIM "	.009±.049	.018±.049	.333±.044	411
TA to LIGM "	.006±.049	.025±.049	.355±.043	411
TA to MP "	-.008±.049	.064±.049	.429±.040	410
N to SNP "	.066±.041	.057±.041	.158±.040	585
N to U inc. "	.042±.041	.068±.041	.252±.039	585
N to SMP "	.094±.041	.021±.041	.320±.037	585
L inc. to SMP "	.130±.041	.054±.041	.306±.037	585

The remaining coefficients of the second order showing the degree of association between

[a] age and stature when each of the facial characters given above and body weight are constant.

[b] age and body weight when each of the facial characters given above and stature are constant.

[c] stature and body weight when each of the facial characters given above and age are constant,

are not tabulated as they number 81 and would take up too much space.

All the correlation coefficients of the first order showing the degree of association between any two of the variables when a third is constant are not tabulated for the same reason. They are 324 in number.

TABLE. 10

Correlation coefficients between the various Pairs of Facial Characters.

Characters.	Children 2 - 5 years No.of obs.	r	Boys 8 - 14 years. No.of obs.	r	Girls. 8 - 14 years. No.of obs	r
TA to N & TA to UIIM	93	.703±.052	343	.661±.030	416	.735±.023
TA to N & TA to UIGM	94	.718±.050	343	.670±.030	416	.763±.021
TA to N & TA to MP	93	.580±.069	343	.549±.038	415	.675±.027
TA to N & Up.Fac.Ind.	94	.142±.101	343	.261±.050	416	.270±.046
TA to UIIM & Up.F.I.	-	-	343	.286±.050	416	.243±.046
TA to MP & U.F.I.	-	-	343	.293±.049	415	.196±.047
N to U Incis & Pal Ht.	87	.424±.088	568	.418±.035	591	.544±.029
Pal Ht.& U.F.I.	87	.200±.103	567	.219±.040	591	.234±.039
N to U Inc. & N to 6|6	94	.891±.021	568	.829±.013	591	.856±.011
L Inc to SMPLM to LBM	98	..804±.036	565	.749±.019	592	.772±.017
N to U Incis & L Incis to SMP	99	.634±.060	565	.567±.029	592	.619±.025
N to 616& L Mol to LBM	94	.626±.063	565	.543±.030	591	.588±.027
Zyg B and B ig B	99	.613±.063				
Zyg B and B at D|D	98	.325±.991				
Zyg B and B or 4|4 at 6|6	-	-	342	.438±.044	416	.572±.033
B of arches 6|6 and U.F.I.	-	-	342	.105±.054	416	.005±.049
B of arch. at D|D & U.F.I.	98	.017±.101	-			
B of arch at 6|6 & N toU Incis	-		342	.409±.045	416	.364±.043
B of arch at 6|6 & Pal Ht.	-	-	342	.153±.053	415	.331±.044
B at D|D or 4|4 & D|D or 4|4	95	.738±.047	338	.731±.025	409	.744±.022
B at 6|6 and 6|6	-	-	342	,842±.016	415	.798±.018
B at 4|4 and 6|6			341	.779±.021	416	.755±.021
B at 4|4 and 6|6			338	..660±.031	408	.656±.028
Bigon B and U.F.I.	-	-	568	.025±.042	-	-
Bigon B and B at 4|4			338	.467±.043	409	.477±.038
LUA & B of archat D|D or 4|4	88	.248±.100	192	.309±.065	234	.251±.061
LUA & B of arch at 6|6			193	.247±.068	234	.209±.063
LLA & B at 4|4 or D|D	88	.361±.093	189	.058±.073	227	.046±.066
LUA and LLA	87	.650±.062	196	.733±.033	234	.713±.032
TA to N and LUA	-	-	194	.232±.068	234	.175±.063
U.F.I and F P I	96	-.081±.101	568	.059±.042	592	.014±.041
Width of Cent & Lat Incis	-	-	214	.535±.049	172	.593±.049

TABLE.

Showing the Correlation between Certain Pairs of Facial Characters when Age is held constant.

	Children 2 - 5 years. No.of obs.	r	Boys 8 - 14 years. No.of obs.	r	Girls 8 - 14 years. No.of obs,	r	Unselected group 100 Boys 9-10 years No.of obs.	r
to U Inc & N to 6|6	94	.827±.033	568	.791±.016	591	.813±.014	97	.780±.040
Inc.toSMP &L MOL tO LBM	98	.736±.046	565	.663±.024	592	.678±.022	98	.686±.054
to U Inc.&L Inc to SMP	99	.476±.078	565	.465±.033	592	.502±.031	100	.459±.079
to 6|6& L Mol to LBM	94	.458±.082	565	.379±.036	591	.412±.034	97	.446±.081
at 6|6 and 6|6	-	-	342	.834±.016	415	.778±.019	-	-
at D|D and D|D	95	.741±.046	338	.682±.029	409	.684±.026	-	-
at D|D and 6|6	-	-	341	.766±.022	416	.708±.024		
at D|D and 6|6	-	-	338	.642±.032	408	.617±.031	-	-
A and LLA	87	.653±.062	195	.732±.033	234	.721±.031	96	.740±.046
to U Inc.and Pal Ht.	87	.225±.102	568	.258±.039	590	.364±.036	97	.435±.082
F.I. and Pal Ht.	87	.001±.107	567	.149±.041	590	.183±.040	97	.276±.094
at 6|6 and Pal Ht.	-	-	342	.022±.054	415	.134±.048	95	.169±.100
B and B at 6|6	-	-	342	.376±.046	416	.476±.038	95	.493±.078
to U Inc.and B at 6|6	-	-	342	.346±.048	416	.229±.047	95	.219±.100
at 6|6 and U.F.I.	-	-	342	.063±.054	416	-.067±.049	95	-.100±.102
to N and TA to UIIM	93	.670±.057	343	.570±.036	416	.657±.028	100	.626±.061
to N and TA to UIGM	94	.688±.054	343	.580±.036	416	.694±.025		
to N and TA to MP	93	.522±.076	343	.387±.046	415	.561±.034	100	.514±.074
to N and U.F.I.	94	-.001±.103	343	.205±.052	416	229± .047	100	.217±.095
to UIIM and U.F.I.	-	-	343	.235±.051	416	.197±.047	100	.252±.094
F I and F P I							100	-.223±.095
B and Bigon B	99	.585±.066	-	-	-	-	-	-
B and B at D|D	98	.320±.091	-	-	-	-	-	-
.I. and B at D|D	98	-.016±.101	-	-	-	-	-	-
and B at D|D	88	.246±.100	-	-	-	-	-	-
and B at D|D	88	.361±.093	-	-	-	-	-	-

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AGE OF FULL STATURE IN FEMALE AND EPIPHYSIAL UNION IN LONG BONES OF LOWER LIMBS

MATTHEW YOUNG
The Institute of Anatomy, University College, London, England

Evidence has been accumulating in recent years in support of the view that some revision may be necessary of the ages of closure usually described as normal for certain of the epiphyses in the present-day anatomical text-books. This statement has special reference to the epiphyses of the long bones of the limbs. Stevenson ('24), in a study of the ages of closure of the epiphyses in a series of age-known skeletons, has referred to the striking divergency of opinion that still exists as to the actual time of union of various epiphyses, including those of the femur and tibia. For the purposes of his investigation on the two bones named in white females he had only eight skeletons between the ages of seventeen and twenty-five years—the ages which are generally regarded as delimiting the period of life within which consolidation of the femur and tibia usually takes place. Of these skeletons, four were of subjects under twenty-one years of age. From a consideration of the state of the epiphyses of these skeletons of white females, the skeletons of a like number of colored females, and about treble the number of skeletons of white and colored males, respectively, in the same age period, providing in the aggregate a group of about thirty skeletons of persons of both sexes at ages under twenty-one years, he came to the conclusion that the age period up to and including the twentieth year was characterized by the completion of all epiphysial union in the so-called long bones and that the epiphyses of the long bones, more particularly the limb bones, were characterized by a remarkable degree of constancy in behavior as regards time of union. Stevenson states he did not find any evidence, in his series of skeletons, of a sensible difference in the dates of epiphysial union in the two sexes, but it must be admitted that the relatively small number of skeletons of females available at the age when consolidation is occurring in the femur and tibia scarcely warrants any stress being laid on this observation so far as these bones are concerned. There still appears to be very general agreement in the view that bony consolidation usually occurs appreciably earlier in females than in males.

The age order of the appearance and union of the normal epiphyses as seen by x-rays has recently been studied by Davies and Parsons ('27). Their investigation is not yet complete, especially with reference to the age of union in certain of the long bones, and they find it is not always possible to be sure from an x-ray film whether complete bony union has taken place or not, but from the evidence available in their data they give the usual ages of union of the epiphyses of the femur and tibia as follows: upper ends of femur and tibia, nineteenth to twentieth year; lower end of femur, nineteenth year, and lower end of tibia, seventeenth to eighteenth year. In the modern text-books of anatomy the proximal epiphysis of the femur is generally described as fusing with the diaphysis at the age of eighteen to twenty years and the distal epiphysis of the tibia at the age of eighteen years, whereas the distal epiphysis of the femur and the proximal epiphysis of the tibia are stated to be incompletely united to their shafts until from the twentieth to the twenty-second year and the twentieth to the twenty-fourth year, respectively.

There is apparently some divergence between these ages of closure and those recently ascertained for the corresponding bones by radiography. This modern method of examination seems to provide a means of determining the ages of epiphysial closure with greater precision. It is probable that the normal age of closure of the epiphyses in these bones will soon be finally established on a sure basis by an extension of the investigation of Davies and Parsons or similar investigations by others, as the accumulation of reliable radiograms of normal subjects will provide adequate numbers to give stable mean values.

In view of the divergency of opinion that still seems to prevail regarding the normal age of closure of the epiphyses of the long bones of the lower limbs, it seemed to be of interest to ascertain the age of attainment of full stature in a fairly long series of living subjects in order to compare it with the ages of epiphysial consolidation just described, to which it may be expected to present a more or less intimate relationship. The complete cessation of growth in stature probably does not occur till the epiphyses of the long bones of the limbs are firmly united to the diaphyses. From a consideration of the usual ages of consolidation of the long bones, as generally accepted at the time, the Anthropometric Committee of the British Association (1883), in a desire to underrate rather than overstate the case, adopted the twentieth year for women and the twenty-third year for men as the age of attainment of maturity. Reliable data which have become available for middle-class English girls suggest, however, that growth in females is on the average completed, in so far as it is dependent on the long bones of the lower limbs, fully a year at least before the age of maturity agreed upon by the Anthropometric Committee. That full stature in the female sex is occasionally attained at or about the midpoint of the nineteenth year may be known in a general way, but little reference has been made to, or emphasis laid upon, it as a general feature. My attention was drawn to the subject of growth completion in females some time ago in analyzing the records of the physical measurements of the girls attending a College of Physical Training—girls who may be regarded, as a class, as active, athletic, and, in the fullest sense, physically fit. The records were collected a few years ago and included certain of the physical measurements of the girls at the College which were very carefully made at frequent intervals during their three years' course of training. The measurements available were the full stature, the stem length, and the chest girth in centimeters, the body weight without clothes in kilograms, and the vital or respiratory capacity in cubic centimeters. The most reliable answer to the question as to when cessation of growth takes place in the female sex is likely to be provided by successive measurements of the same group of girls from year to year. Though general inferences on the point may be drawn from the average measurements of the groups at successive ages in a larger series, such data are apt to be vitiated by the circumstance that there may have been some special selection resulting in the inclusion of a larger proportion of the taller types at the later than at the earlier ages.

From the cards containing the records it was possible to obtain a series of fifty, relating to girls who had been measured at more or less closely corresponding periods in their nineteenth, twentieth, and twenty-first years. For this group of girls the mean values of each of the two physical traits, full stature and stem length, were calculated with their standard errors. These statistical constants with the standard deviations and coefficients of variation of the characters are shown in table 1. A survey of this table shows that, while the average full stature of the girls of a mean age 20.5 years is about 7.5 mm. in excess of the corresponding average value at the age of 18.5 years, the difference at these ages cannot be considered significant as it is less than its standard error. The fact that the mean stature increases progressively with age may be regarded as a suggestive feature and as evidence of actual growth, even though the differences are so small and not sensible statistically. It must be noted, however, that practically the whole increase in mean full stature that is shown with age is accounted for by an increase in the stem or trunk length. At the upper and lower epiphysial plates of the vertebrae, from which the thickened circumferences of the upper and lower aspects of the vertebral bodies are derived, are described as not fusing with the remainder of the bones till the twenty-fifth year, there is obviously still a potentiality of further growth in the spinal region for some time after the nineteenth year, but growth in stature in later adolescent life is usually regarded as occurring in the long bones of the lower limbs. The fore-

TABLE 1

Showing the statistical constants of full stature and stem length at successive ages from eighteen to twenty years both in the same series of fifty girls and in the total numbers available at each age

Mean age (years),	18.5	19.5	20.5	21.5
		Full stature		
Mean (cm.)	163.34±0.65	163.80±0.66	164.10±0.63	—
Standard deviation (cm.)	4.56	4.64	4.44	—
Coeff. of variation (per cent)	2.79	2.84	2.71	—
Number of observations	50	50	50	—
Mean (cm.)	162.62±0.43	163.28±0.39	163.56±0.43	163.22±0.57
Standard deviation (cm.)	4.65	4.85	4.91	4.56
Coeff. of variation (per cent)	2.86	2.97	3.00	2.80
Number of observations	119	152	128	64
		Stem length		
Mean (cm.)	85.66±0.39	85.74±0.36	86.26±0.37	—
Standard deviation (cm.)	2.75	2.57	2.58	—
Coeff. of variation (per cent)	3.21	2.99	2.99	—
Number of observations	50	50	50	—
Mean (cm.)	85.41±0.24	86.00±0.22	85.95±0.23	85.95±0.32
Standard deviation (cm.)	2.61	2.67	2.60	2.59
Number of observations	3.05	3.11	3.03	3.02
Coeff. of variation (per cent)	119	152	128	64

going results seem to indicate quite clearly that, if any appreciable growth in stature takes place in girls after they attain the midpoint of their nineteenth year, the site of the increase is the vertebral region and not the long bones of the lower limbs. In view of the fact that the average amount of increase of stature noted is of such a small order that it is just equivalent to that which has been described as normally occurring on the average in groups of the same persons when measured at different times of the day, or in fresh and fatigued states of the body—and presumably such an increase as might arise from prolonged training and experience in bracing up the figure—there would appear to be a reasonable basis for the inference that, in the fifty girls examined, no actual increase in average stature has taken place after the midpoint of the nineteenth year. These results, derived from the repetition of measurements in the same group of subjects, are supported by the mean values obtained from the measurements of the whole series of girls exceeding 120[1] in number at each of the successive average ages 18.5, 19.5, and 20.5 years (table 1).

The original data on which this paper is based relate only to measurements of females, but a few of the average values for full stature and stem length in males at successive ages, based on long series of observations exceeding 300 at each age, which were published recently by Ruger and Stoessiger ('27), may be cited to indicate briefly the age of completion of growth in the other sex. The figures show that stem length has practically attained its maximum at the mean age 19.5 years. Full stature actually reaches its maximum at the age of 21.5 years, but the increase in mean value at this age over that shown at 19.5 years is only 1 mm. The last appreciable increase in full stature occurs between the ages 18.5 and 19.5, when it equals 5 mm. This increase in full stature is, however, only equivalent to that shown in mean stem length in the same age interval. The figures for males thus seem to indicate a very similar relationship to that shown in females, namely, that growth in full stature, in so far as it is dependent on the long bones of the lower limbs, ceases at the average age of 18.5 years, and that any further growth in stature thereafter is accounted for by the increase in stem length.

[1] Including, in each age group, one measurement only of each girl.

SUMMARY AND CONCLUSIONS

The analysis of measurements of full stature and stem length obtained at yearly intervals from age 18 upward in the same group of fifty middle-class English girls of good physical type shows that full stature, in so far as it is dependent on lengthening of the lower limbs, is attained by the midpoint of the nineteenth year, on the average. Ruger and Stoessiger's data seem to indicate a very similar relationship in males. This average age of cessation of growth is approximately a year earlier than the age at which the last epiphysis in these bones to unite is completely fused, as determined by radiography in the living subject and by observation of macerated age-known skeletons by Davies and Parsons, and Stevenson, respectively. These results support the advancement of the usual age of consolidation of the tibia and femur advocated by these authors, and are opposed to the view that epiphysial union therein is often delayed till the twenty-second or twenty-fourth year as is still described in modern text-books of anatomy. Considering the relatively small number of observations on which the paper is based, the results, while suggestive, cannot be regarded as conclusive. Two questions appear still to require a definite answer. They are: 1) Is there no sexual difference in the time of union of the epiphysis of the long bones, as Stevenson asserts, or does consolidation occur earlier in the female than in the male, as is commonly believed? 2) Does cessation of growth in stature cease before bony union is complete, i.e., is there a stationary period in the epiphysial proliferation before calcification and ossification ensue?

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Anthropology, Physical. Young.

The Problem of the Racial Significance of the Blood Groups.

By Matthew Young, M.D. **116**

In recent years much attention has been directed to the possibility of using blood group differences as an aid to the elucidation of racial origins and relationships and to the differentiation of mankind into racial types. Many data have been published giving the percentages of various peoples in different parts of the world that fall into the four blood groups that have been described and are now generally recognised. In different geographical areas or among different populations considerable variation in the relative proportions of the four blood groups has been found, and attempts have been made to classify mankind into racial groups on the basis of these percentage differences or on factors derived therefrom. The evidence so far available, however, presents difficulties of interpretation. The relative distribution of the blood groups cannot apparently be brought into agreement either with that of the racial types hitherto recognised and differentiated on the basis of physical characters or with geographical conditions. In view of this apparent lack of harmony, it seems to be of interest to bring under review and to analyse the data relative to proportions of the blood groups in the inhabitants of different areas, that have recently accumulated, with the object of trying to assess the importance and the reliability of this characteristic as an additional aid to racial differentiation and classification.

As is now well known, the classification of the blood into groups was due primarily to Landsteiner (1901), who, having found that the serum of certain human bloods agglutinated or clumped the cells of certain other human bloods, proceeded to classify bloods into three groups based on the agglutination reactions which he obtained. Subsequently, it was found by other observers that there were exceptional cases that apparently did not fall into these three groups and Jansky in 1907 made a definite classification into four groups which he referred to by numbers I, II, III and IV. Moss, a short time later, described a second numerical grouping in which numbers IV and I in Jansky's classification were interchanged. Landsteiner suggested that the groups should be classified according to the iso-agglutinogen content of the cells instead of numerically. Thus we have the four groups usually defined as O, A, B and AB, the first of which consists of bloods wherein the red cells carry neither of the agglutinable factors or agglutinogens; the second in which the red cells carry the A factor alone; the third in which they carry the B factor alone, and the fourth in which both the A and B agglutinable factors of Von Dungern are present. At various times, anomalous bloods have been described which do not appear to fall into any one of the four groups mentioned; but most observers seem now to be more or less in agreement in the view that these apparently exceptional cases can be explained as usually due to pseudo-agglutination, low agglutinogen-agglutinin titre, failure of complete adsorption in adsorption experiments or somewhat allied conditions and that the four well-recognised groups are sufficient to include all cases (*see* Dyke, 1927).

Interest in the subject of the application of blood grouping to anthropology and racial differentiation was first aroused by the work of L. and H. Hirschfeld (1919), who showed that the percentages of the blood groups varied in different peoples and that the variation was related to geographical distribution. They found that the proportion of agglutinogen A, characteristic of Group II or Group A, appeared to predominate greatly over the proportion of agglutinogen B in European peoples, whereas the factor B predominated over the factor A in Asia and Africa. Factor A decreased in passing from west to east and B decreased in passing from

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east to west. These conclusions were drawn from the examination of about 500 members of each of 16 different nations or peoples. They classified these peoples on the basis of a " biochemical index " or racial index, namely, the ratio of the percentage of the A factor to the percentage of the B factor or $\frac{\%A + \%AB}{\%B + \%AB}$ into three groups: (1) European, (2) Intermediate and (3) Asio-African. The races with an index higher than $2 \cdot 5$ were assigned to the European type, those with an index of less than 1 to the Asio-African type, whereas those with an index between $1 \cdot 3$ and $1 \cdot 8$ were classed as intermediate. The data furnished by more recent observations on different peoples have shown that the chosen limits of this subdivision are quite arbitrary as intermediate values of the index occur, and the values now available for the different peoples seem to form a more or less continuous series. Steffan (1926) calculated Hirschfeld's " biochemical index," which he describes as the biological race index A (or the Atlantischer index), for a long series of blood group records of different peoples, including many not available to the Hirschfelds. He also tabulated the values of an index G (the Gondwanischer index), the reciprocal of the A index. Having indicated the location of the populations under consideration on maps, he drew curved lines connecting peoples with corresponding values of the indices, inserting broken lines to indicate the probable distribution of intervening values. The maps resemble contour maps and seem to show that the centre of distribution of races with a high A index or with a relative preponderance of persons falling into the A or II blood group was in the north-west of Europe, whereas the centre of distribution of the G type was in China, in the vicinity of Peking. Assuming that races with high A and G values were primitive, Steffan then discussed the probable migratory history of these. Ottenberg (1925) also made a study of more material than was available to the Hirschfelds and considered that, so far as blood groups are concerned, the races represented may be readily classified into six strikingly different types, namely, (1) European, (2) Intermediate, (3) Hunan, (4) Indo-Manchurian, (5) African-south-Asiatic and (6) Pacific-American. Ottenberg made the reservation, however, that he put forward this classification as merely provisional and as based on the scanty knowledge existing at the time.

Both Bernstein and Snyder have pointed out that the biochemical index as used by the Hirschfelds is not an adequate differential criterion mathematically, and that the actual frequencies of the hereditary factors, A and B, in a population, frequencies which can be calculated easily for any population wherein the percentages of the four blood groups are known, should be used. Snyder (1926) presents his data in the form of a chart in which p and q, the frequencies of the factors A and B in the different peoples, are the coordinates. In this correlation table the peoples investigated appear to fall into more or less natural groups. On the basis of the relative proportions of the p and q factors, the various peoples were divided arbitrarily into types. These types are in substantial agreement with Ottenberg's, although there has been a redistribution of a few of the component members of the groups. They are seven in number, as the Australian type has been set apart from the Pacific-American, and are as follows: (1) European, (2) Intermediate, (3) Hunan, (4) Indo-Manchurian, (5) Africo-Malaysian, (6) Pacific-American and (7) Australian. Snyder emphasised the fact, however, that it is not implied that because two peoples occur in the same class they have the same racial history, but only that they contain approximately similar amounts of the A and B factors. He states that the types are purely arbitrary, are subject to revision, and merely serve as a working basis for racial classification on serological grounds. Wellisch (1927) calculated a modified race index, the Bernstein index, *i.e.*, the ratio of the percentage of p to the percentage of q, or p/q, and found that the use of this index made comparatively little change in the relative positions of the various peoples arranged in accordance with the values of the Hirschfeld index.

The expectation that the proportional distribution of the blood groups in a people may shed light on its racial origin is not unreasonable, as it is now generally agreed that the factors A and B are inherited in a typical Mendelian manner. For some time it was commonly believed that the factors were inherited as two independent pairs of Mendelian factors, but recent observations suggest that the mode of inheritance may be more adequately explained on the hypothesis that the inherited factors are a series of three multiple allelomorphs. Moreover, evidence has been furnished by certain observers, including Ottenberg (1923), which tends to show that the proportions of the four blood groups are remarkably stable in a given population, provided no outside admixture occurs. They may apparently remain the same for an indefinite number of generations.

Records of the percentages falling into the four blood groups in the various peoples throughout the world are steadily accumulating. Many of these have been collected from different publications by Snyder (1926), who provides a long list of data, including some original observations. These data and other data collected from various sources, principally from Scheidt's memoir (1927), provide the material for the present inquiry into some of the points at issue in regard to the racial significance of the blood groups.

The hypothesis has been advanced by the Hirschfelds that originally all bloods belonged to Group O and that the A and B factors arose as mutations, factor A in the European zone and factor B in the Asiatic zone, and that the population groups with intermediate proportions of these factors have arisen by admixture or commingling of peoples bearing the respective factors. Some such hypothesis might certainly readily explain the predominance of the A factor in western Europe, the B factor in Asia and the intermediate proportions of the two factors in the intervening area. Snyder (1926) finds in the relatively high proportion of Group O in the pure-blooded American Indians, whom he selected as a people specially suitable for the study of racial admixture, support for the view that originally human blood was all of Group O. He contrasted the proportions in the pure bloods with those in Indians with white admixture and found the proportion of Group O considerably reduced and the proportion of Group A increased and that the transfer from Group O to Group A seemed to correspond with the amount of admixture. Coca and Diebert (1923), in view of the high proportion of Group O in the American Indians, suggested that this people became separated from the human family before the appearance of the iso-agglutination factors in the blood and that the existence of these elements in the blood of some of the Indians examined by them was due to the admixture with white people. The acceptance of such a possible date of appearance of the factors in the human stock is, however, rendered less probable as a result of Landsteiner and Miller's (1925) recent observations, which appear to show that factors A and B, practically identical with those of human beings, occur in the blood of anthropoid apes.

A survey of the available data reveals the fact that the people with the highest percentage of Group O are the North American Indians, in whom, among the pure bloods, a percentage as high as 91·3 has been recorded by Snyder. In other groups of North American Indians, Group O forms 78 per cent. of the total. Among Polar Eskimos, Henbecker and Pauli (1927) have found the proportion of Group O to be 81 per cent. of the total, and these authors suggest that the pure Polar Eskimos were probably also all of Group O as the small proportion of persons falling into the groups other than O were generally shown to be half-breeds. In the remaining data, percentages of Group *O* equal to or exceeding 50 have been recorded for relatively few population groups. Among these are the Filipinos with 64 per cent., the Australian aborigines with 56 per cent., the Icelanders with 55·6 per cent., the Melanesians (N. Guinea) with 53·7 per cent., the Bogobos (Philippines) with 53·6 per cent., the South African natives with 52 per cent., the white Australians with 52·6 per cent., the Swedish Lapps and Igorotos (Philippines) each with 51 per cent. and Brazilians with 50 per cent. Recent data from the Philippines for certain relatively unmixed tribes suggest that the proportion of Group *O* is not so high there as was formerly believed.

It has been suggested by Snyder (1926) that the majority of the peoples with a proportion of Group *O* exceeding 50 per cent. are island peoples or peoples living in regions more or less isolated, and so presumably less liable to admixture. This description is certainly applicable to many of the peoples indicated, but some other populations showing amongst the lowest proportions of Group *O*, namely, the Ainu with 19 per cent., South Koreans with 19·9 per cent., North Japanese with 29 per cent., and North Chinese (Shantung) with 21 per cent., might be similarly described. The proportion of Group *O*, namely, 52 per cent., in Australian whites is based on nearly 1,200 observations and so may be considered fairly reliable. The proportion of the same group estimated for the consecutive series of 100 observations of this total has been shown by Tebbutt (1923) to range in value from 46 to 65 per cent. This divergence indicates the amount of variation that may be found in a fairly homogeneous population when the number of observations does not exceed 100. In view of the relatively high proportion of Group *O* in the white Australian population, which cannot be described as being other than of comparatively recent foundation and mainly, though not entirely, of British origin—Carr Saunders (1927) states that well over 90 per cent. of the population of Australia has British or Irish antecedents—it is evident that not too great stress can be laid upon the significance of a proportion of Group *O* just exceeding 50 per cent. in many of the islands or relatively isolated regions described by Snyder as indicative of lack of admixture therein.

Though information regarding the blood groups of the various peoples throughout the world is steadily accumulating, the percentage distributions of the blood groups published are based, in many instances, on relatively small numbers of observations. It is obvious that, in view of the possible errors of sampling under such circumstances, apparent differences may not be statistically significant; in other words, the numbers available may not be sufficient to indicate that any importance can be attached to the difference shown. This defect may be illustrated by the application to a selection of the data of the method of analysis devised by Prof. Karl Pearson (1911) to ascertain the probability that, given two frequency distributions of phenomena, one distribution is really different from the other to a greater degree than can reasonably be supposed to have arisen by the operation of chance alone. The formula used is given below.*

Professor Pearson has used this method to determine whether various populations were differentiated with regard to hair colour. By this test, the proportions in the corresponding blood groups in samples of any two populations can

*

$$\chi^2 = S_1^s \left\{ \frac{NN'\left(\frac{fp}{N} - \frac{f'p}{N'}\right)^2}{fp + f'p} \right\}$$

where fp and $f'p$ represent the frequencies in corresponding groups of the two samples compared, N and N' represent the total numbers in the two samples and S_1^s represents the summation of the several terms. The required probability that the two samples are undifferentiated, *i.e.*, did come as random samples from the same population, may be found by looking up the value of P corresponding to the ascertained χ^2 and n', the number of classes, in the tables given on pp. 26–29 of Pearson's Tables for Statisticians and Biometricians.

be compared and the probability that such differences as occur may arise fortuitously can be determined. The test has been applied: (1) to a selection of samples of populations from the same nation or the same geographical region, and (2) to certain samples of populations that, according to present conceptions of racial relationships, apparently belong to different racial groups. The application of the test has revealed some rather interesting results. In the first place, comparing the blood group distributions in two samples of population from the same nation, it is found that in a number of instances among the available data there is a distinct differentiation—the differences are greater than are likely to arise fortuitously on the numbers examined. Thus the Germans* from Schleswig-Holstein differ significantly from the Germans in Leipzig, the Italians examined by the Hirschfelds differ from the Italians examined by Mino, the Americans examined by Snyder and Moss both differ from the Americans examined by Culpepper, the Hungarians examined by Von Jeney differ from the Hungarians examined by Manuila, the Roumanians residing in the mountainous regions differ from the Roumanians in the valleys (Popoviciu), both the Armenians examined by Parr and those examined by Altounyan differ from the Armenians of Kossowitch, the Japanese in the vicinity of Hida from the Japanese of Nagoya and of Niigata, the Ainu recorded by Ninomiya from the Ainu of Nakajima; one group of Philippine Moros diverges significantly from a second group, each comprising about 500 persons, though the groups presented a very close resemblance in physical characters. The lack of concord in distribution of blood groups in groups of Moros indistinguishable as regards physical type was first pointed out by Grove (1926). On the other hand, neither a sample of the English population nor of Australian colonists can be regarded, on the numbers available, as differentiated in respect of their blood group distribution from the pure-blooded Australian aborigines, the American negroes are not differentiated from Russians, though they appear to diverge significantly from Senegalese, nor are Spanish Jews (Hirschfeld and Hirschfeld) differentiated from Chinese, nor Manchus from the Ainu, nor Viennese from the Japanese, nor Egyptians from the Ainu, nor Swedes from Lapps, nor Germans in Berlin from Turks, nor Germans in Kiel from Bulgarians, nor Ukrainians from South Koreans. The lack of differentiation between the blood group distributions in Germans and Turks and Bulgarians respectively is of interest as in Snyder's serological classification of the races, the Germans fall into the "European" type, whereas the others are described as of "Intermediate" type.

Unfortunately, there is no general agreement among anthropologists in regard to the racial groups into which mankind may or should be divided on the basis of physical characters, among which, skin colour, form and distribution of hair on scalp and body, stature, shape of head and characters of face, nose and eyes are those usually relied upon. The particular physical traits or the number of traits that are to be taken into account in differentiating races is still a matter of individual opinion. Thus the term "race" may be restricted to the three broad groups of people distinguished by degree of pigmentation, white, dark and yellow, or these may be subdivided by taking into consideration other characters such as type of hair or form of head. The limits of the racial groups will obviously depend on the characters selected as criteria. A broad, general classification of racial types based on physical characters which has been found sufficiently comprehensive is the following: (1) Australoid, (2) Negroid, (3) Mongolian, (4) Central or Alpine, (5) Mediterranean and (6) Nordic. The main point of contrast between this racial grouping based on physical characters and Snyder's serological grouping is that,

* The peoples whose blood groups are compared, the names of the observers, the number of observations on which the comparisons are based, and the resulting values of χ^2 and P, with comments thereon, are shown in Table I.

whereas Snyder's scheme proposes no subdivision of the western European type, which is a mixture of the three types, Central or Alpine, Mediterranean and Nordic, it differentiates the groups Hunan, Indo-Manchurian and Pacific-American, which, in large part at least, would fall into the group broadly classed as Mongolian in the first scheme. This subdivision is of special interest, as, according to Haddon, there is now a Mongol nation and not strictly speaking a Mongol "race," but the term "Mongol" has become established by constant usage for the group of peoples. Race names such as Nordic and Alpine have been described as merely convenient abstractions helping us to appreciate broad facts. Wellisch (1927) seems to suggest that, on the average, the Nordic, Mediterranean and Alpine races in Europe show a gradually decreasing Bernstein index, (p/q), indicating a fall in the relative proportion of Group A in that sequence. It is doubtful, however, if the differences pointed out by him can be considered significant. Scheidt (1927) has made a detailed analysis and comparison of the proportions of the blood groups in many different peoples. In numerous cases he has calculated the standard errors of the percentages in the different groups and has thus been able to determine if differences in corresponding groups in various peoples may be considered significant on the figures available. He found evidence that preponderatingly Nordic people (in Angeln and Pellworn) could be distinguished by a greater A frequency. It appeared considerably more uncertain whether the Alpine populations (Alpine being used as indicative of area occupied and not in an ethnological sense) were distinguished from them by a smaller A frequency, particularly if it is accepted that the population of Peterstal (in the Black Forest) in its other racial characters stands nearer to the Alpine population than perhaps the lower German peoples. He states, further, that the comparisons of the Italian groups with the north European groups show only a few reliable differences. Results from a comparison of certain European peoples regarded as mainly belonging to these different racial types seem to be somewhat equivocal. Taking the Swedish percentage distributions recorded by Lindberger as representative of the Nordic type, the distribution of the blood groups in this "race" is not differentiated from that shown in a group of about 500 Alpines in the Black Forest (the Alpine group has the higher proportion of A), but is differentiated from Serbians, who may be regarded as mainly of Alpine type. The distribution of the blood groups in Swedes (Lindberger) is significantly different from that in one group of Italians examined by Hirschfeld, but not from that of another group examined by Mino. Hirschfeld's data appear to have been derived from all over Italy and Mino's mainly from the north of Italy, but they may be taken generally as more or less representative of the Mediterranean type. The distribution of the blood groups in Swedes (Lindberger), representative of the Nordic type, is significantly different from that of the Germans in Schleswig-Holstein, who are described also as being mainly of the Nordic type. This is the district in which the Nordic type is said to be best preserved in Germany. The distribution of the blood groups in the Serbians (the Hirschfelds) differs significantly from that in both the Italians examined by the Hirschfelds and in those examined by Mino; whereas the distribution of the blood groups in the Sardinians, who may be regarded as mainly of Mediterranean type, is not significantly different from that of Slovacs in Roumania, who may be considered as predominantly of Alpine type. From these results it is obvious that, with the data available, no very definite inferences can be drawn regarding the existence of any significant or characteristic differentiation in the blood grouping of the three European types, Nordic, Alpine and Mediterranean, although, according to many anthropologists, these three types represent three very clearly defined and distinctive races, which appear almost as much differentiated from one another in regard to physical characters as any one of them is from the rest of the groups of the human family, Australian, Negro and Mongol.

The principal points that appear to emerge from the analysis and study of the data may now be summarised briefly and discussed. It seems to be clearly established that whereas the relative proportions of the blood groups vary considerably in the different peoples examined, there is a definite preponderance of Group III or the factor *B* in the peoples of the eastern Asiatic zone and a relative excess of Group II, indicating a preponderance of the *A* factor, in the peoples of the western European zone. There appears to be some evidence in favour of the hypothesis that human blood was originally all of Group *O*, or devoid of agglutinogenic factors, but when or where the separate mutations resulting in the appearance of the *A* and *B* factors in the human stock occurred and whether they were single or repeated is still a matter of pure conjecture. The maximum concentration of the respective factors *A* and *B* in west Europe and China or India would suggest that the points of origin were located in these areas. The relative paucity of the *A* and *B* factors in certain "races," such as the American Indians and the Eskimos, has been attributed to the separation of these peoples from the primitive stock before the appearance of the agglutinogenic factors; but the lack of differentiation between the blood group distributions of Australian colonists and full-blooded Australian aborigines, the latter of whom may be regarded as undoubtedly the most primitive race now living and who represent the survival with comparatively slight modifications of perhaps the primitive type of the species (Elliot Smith), suggests that no such inference can be drawn from the Australian data.

The blood groups are known to be very stable under varying environmental conditions. The concordance between the distribution of the groups in Hungarian gypsies as examined by Verzar and Weczeczky (1922), descendants of some who are believed to have migrated from India in the twelfth century, and the distribution of the blood groups in Indians of the present day as examined by the Hirschfelds, and its divergence from that of the Hungarians amongst whom they live has been frequently cited as evidence of the persistence of the type of blood grouping from generation to generation in the absence of crossing. It is very doubtful if the results of 1,000 observations can be accepted as in any way representative of the blood grouping in India, in which there appears to be evidence of several racial types. Perhaps too much emphasis has been laid on this particular example of apparent persistence of blood type. Peoples as far apart from one another and as divergent in physical type as the Senegalese and the Sumatrans exhibit identical distributions of the blood groups, whereas the distribution in the former group diverges significantly from that shown in the Melanesians on New Guinea, who are negroid in type and probably derived from the same primitive stock. The fact that the relative distributions of the blood groups are apparently not significantly differentiated in data derived from peoples as divergent in physical characters as Viennese and Japanese, Egyptians and Ainu, Russians and American Negroes, Spanish Jews and Chinese, Australian colonists and Australian aborigines and Swedes and Lapps respectively, as shown in Table I, although in most cases these inferences are based on fairly large numbers of observations, quite comparable in extent at least with those of which blood group records appear frequently at the present time in publications, suggests that the blood group differences may not be so valuable in racial differentiation as is now more or less generally believed. It is doubtless true that resemblances and differences in blood group proportions may give in many cases some indication of racial relationships, but with the available data and in the present state of knowledge regarding the probable origin of the mutations which may have appeared not once only but repeatedly, it is difficult to draw any but the most general inferences regarding possible relationships. So far as can be seen at present, there would appear to be small warrant for the belief or claim that the evidence supplied by blood grouping will provide a complete and satisfactory basis for the classification of racial types and that more importance should be attached to this feature than to other racial characteristics such as head or hair form or skin colour. When more is known regarding the distribution of blood groups in other samples of peoples of definite racial types, of whom no record has yet been obtained, the characteristic may be shown to be of greater value as a criterion of racial differentiation and classification, but the present indications are that blood grouping will not replace but may possibly supplement in some measure the racial criteria at present relied upon.

The criticism may be advanced that, in the present study, I have selected the pairs of unlike race based on anthropological characters which do not show differentiation in their blood grouping and the pairs alike anthropologically which do show differentiation in their blood groups; in other words, laid emphasis upon the "failures" and ignored the "successes." If it be supposed that on general anthropological grounds six races can be distinguished, in order to provide a crucial test of the value of blood group distribution as a racial criterion, two samples of blood distributions from every possible pair of groups of similar race and from pairs of unlike race should be compared. If the percentages of differentiations were significantly the same in the two classes, it might be considered conclusive proof that blood grouping was of little value as a racial criterion. A survey of Table I, in which a considerable number of comparisons of blood group distributions of population groups selected from among the most reliable and most comprehensive data available at once reveals a difficulty. It is apparent that in relatively few instances can the proportions recorded be regarded as representative of a definite "race"—a group subject for a long period to a stable environment and mating with one another freely (Karl Pearson). As already mentioned, there is no unanimity of opinion among anthropologists as to the most suitable classification of peoples into racial groups. Perhaps there may not be sufficient warrant for the assumption that the classification of races based on physical characters can be regarded as final or conclusive, nor is it certain that the classification based on blood groups should be expected to coincide with the former. It is well known that any racial classification depends wholly on the criteria used and that even the use of alternative groups of two or three characters would provide dissimilar classifications. From the considerable variation shown in the percentage distributions of the blood groups in successive hundreds of the same series of Australian colonists by Tebbutt, it is apparent that little reliance can be placed on percentage distributions based on even 100 observations, although numerous results based on smaller numbers than this are published and conclusions drawn from them. If the attempt be made to obtain more extensive or more adequate records by combining the figures of different observers, the risk is very great that the special features of definite anthropological groups will be obscured, if not lost. For example, the percentage distributions in fully 11,000 Poles recorded by Halber and Mydlarski, and of approximately 9,500 Japanese obtained from the aggregated data of several Japanese observers, including Nakajima, Kawaishi, Furuhashi, Masubara, Hara, Kishi, etc. (for other names *see* Furuhata, T. and Kishi, T., 1926) are as follows:

Population Sample.	*Blood Group Percentages.*				*Total No. of Observations.*
	O	*A*	*B*	*AB*	
Poles	32·5	37·6	20·9	9·0	11,488
Japanese	30·4	38·5	21·5	9·6	9,337

Similarly, fairly large groups of Russians and Chinese give the following figures:

Russians from Moscow (Wagner)	32·0	38·5	23·0	6·5	2,200
Chinese from Hunan (Li Chi Pan)	31·3	38·1	20·7	9·9	1,500

TABLE 1.

Samples of Peoples Compared.			χ^2	P.	Remarks.
1,000 Viennese (Hoche & Moritsch)	and	500 Japanese in Tokio (Nakajima) -	1·73	0·63	Undifferentiated.
417 Egyptians (Mooko & Dolbey)	and	205 Ainu (Ninomiya) - - - -	2·49	0·48	„
500 Swedes (Lindberger)	and	183 Lapps (Schött) - - - -	1·33	0·73	„
1,176 Australian Colonists (Tebbutt)	and	191 Australian Aborigines—pure bloods (Tebbutt).	3·31	0·35	„
500 Englishmen (Hirschfeld & Hirschfeld).	and	191 Australian Aborigines—pure bloods (Tebbutt).	5·52	0·14	„
1,000 Russians (H. & H.)	and	500 American Negroes (Snyder) - -	5·69	0·13	„
500 Spanish Jews (H. & H.)	and	1,000 Chinese (Liang) - - - -	2·42	0·48	„
435 Manchus from Mukden (Fukumachi, Kirihara, Haku).	and	600 Ainu (Ninomiya, Kishi, Nakajima)	0·37	>0·80	„
750 Germans in Berlin (Schiff & Ziegler).	and	500 Turks (H. & H.) - - - -	1·09	0·78	„
500 Germans in Kiel (Steffan)	and	500 Bulgarians (H. & H.) - - -	4·42	0·22	„
400 Ukrainians (Manuila)	and	171 South Koreans from Zennan (Kirihara, Kaku).	4·53	0·21	„
500 Swedes (Lindberger)	and	502 Alpine Germans in Peterstal, Baden.	3·33	0·35	„
500 Swedes (Lindberger)	and	1391 Italians (Mino) - - - -	2·84	0·41	„
546 Sumatrans (Bais & Verhoef)	and	500 Senegalese (H. & H.) - - -	0·41	>0·80	„
1000 Indians—Natives of India (H. & H.).	and	385 Hungarian Gypsies (Vérzar & Weczeczky).	4·51	0·22	„
461 Slovaks in Roumania (Manuila)	and	947 Sardinians (Romansen) - -	6·38	0·10	„
500 Swedes (Lindberger)	and	533 Swedes (Hesser) - - - -	2·11	0·55	„
500 Swedes (Lindberger)	and	436 Norwegians (Jerivell) - - -	0·88	>0·80	„
582 Germans in Schleswig-Holstein —fr. average-sized towns (Gundel)	and	345 Germans in Schleswig-Holstein—fr. small towns (Gundel).	2·15	0·55	„
500 Bulgarians—Prisoners of War (H. & H.).	and	372 Bulgarians in Roumania (Manuila)	5·98	0·11	„
500 Negroes in U.S.A. (Snyder)	and	250 Bantu Negroes (Snyder). - -	1·15	0·77	„
1176 Australian Colonists (Tebbutt)	and	500 Englishmen (H. & H.) - - -	6·65	0·09	„
316 American Indians var. tribes (Haskell).	and	457 Navajo Amer. Indians—full bloods	4·61	0·21	„
112 Middle Koreans fr. Chukoku (Kirihara).	and	184 Middle Koreans fr. Phyenyang (Fukamachi).	6·72	0·08	„
787 Middle Koreans (Kirihara, Fukamachi).	and	354 North Koreans (Kirihara) - -	7·80	0·05	„
783 Hungarians in Debreczen (V. & W.).	and	648 Hungarians in Tetish-Transylvania (Manuila & Popoviciu).	5·33	0·15	„
476 German Colonists in Hungary (V. & W.).	and	348 Germans fr. Heidelberg (von Dungern & Hirschfeld).	5·34	0·15	„
1000 Germans fr. Leipzig (Sucker)	and	300 Saxons in Roumania (Manuila) -	11·60	0·0091	Differentiated.*
1000 Germans fr. Leipzig (Sucker)	and	1100 Germans fr. Köln (Wiechmann & Paal).	47·23	0·000000	„
1740 Germans fr. Berlin (Schiff)	and	1100 Germans fr. Köln (W. & P.) -	36·08	0·000001	„
1000 Germans fr. Leipzig (Sucker)	and	1679 Germans fr. Schleswig-Holstein (Schütz & Wohlisch).	50·01	0·000000	„
1006 Germans fr. Frankfort (Schneider).	and	1100 Germans fr. Köln (W. & P.) -	10·72	0·0136	„
1000 Germans fr. Leipcig (Sucker)	and	348 Germans fr. Heidelberg (von Dungern & Hirschfeld).	7·95	0·047	„
512 Danes in Denmark (Johannsen).	and	800 Icelanders (Jonsson) - - -	20·18	0·000158	„
500 Serbians (H. & H.)	and	461 Slovaks—School children in Roumania (Manuila).	14·90	0·0018	„
947 Sardinians (Romansen)	and	559 Italians (Rizzati) - - -	42·27	0·000000	„
947 Sardinians (Romansen)	and	150 Maltese (Snyder) - - - -	12·27	0·0066	„
2500 German Swiss in Zürich (Clairmont).	and	543 Swiss (Plüss) - - - -	10·98	0·0017	„
383 Westphalians — children of parents from western districts.	and	321 Westphalians—children of parents fr. eastern districts (Klein & Ostoff).	44·07	0·000000	„
225 Scots (Alexander)	and	403 Englishmen (H. & H.) - - -	18·21	0·000405	„
403 Englishmen (H. & H.)	and	218 Englishmen in U.S.A. (Buchanan & Higley).	18·62	0·000336	„
204 Filipinos (Cabrera & Wade)	and	183 Filipinos (Pascual) - - -	27·16	0·000006	„
183 Lapps (Schött)	and	199 Swedish Lapps (Reitz) - -	11·15	0·0111	„

* The peoples compared are only considered to be significantly differentiated in their blood group distributions when P falls below a value of 0·05, or 1 in 20.

TABLE 1—*continued.*

Samples of Peoples Compared.			χ^2	*P.*	Remarks.
510 Russians fr. Kasan (Wagner)	and	808 Russians from Charkow - -	9·46	0·024	Differentiated.*
363 Koreans fr. Seoul (Fukamachi)	and	502 North Koreans (Kirihara) - -	13·42	0·0039	,,
1500 Chinese in Hunan (Li-Chi-Pau)	and	592 Chinese in Sumatra—Chiefly from S. China (Bais & Verhoef).	44·35	0·000000	,,
1000 Chinese (Liu & Wang)	and	592 Chinese in Sumatra (B & V.) -	20·19	0·000158	,,
1000 Russians (Hirschfeld & Hirschfeld).	and	400 Ukrainians (Little Russian school children in Roumania) (Manuila).	102·68	0·000000	,,
238 Senegal Negroes (Hirschfeld & H.).	and	252 Bantu Negroes - - - - -	9·38	0·025215	,,
476 German Settlers in Hungary—near Budapesth (V. & W.).	and	1000 Germans from Leipzig (Sucker) -	16·97	0·000707	,,
1293 South Chinese fr. Hunan	and	1000 North Chinese fr. Peking - -	75·40	0·000000	,,
100 Australian Colonists (Tebbutt)	and	2nd 100 Australian Colonists fr. same series (Tebbutt).	11·44	0·009	,,
1000 Germans in Leipzig (Sucker)	and	1679 Germans in Schleswig-Holstein (Schütz & Wohlisch).	50·1	0·000000	,,
1391 Italians (Mino)	and	500 Italians (H. & H.) - - -	27·9	0·000004	,,
5000 Americans (Culpepper)	and	1600 Americans (Moss) - - -	101·30	0·000000	,,
5000 Americans (Culpepper)	and	1000 Americans (Snyder) - - -	27·84	0·000002	,,
1172 Hungarians (von Jeney)	and	688 Hungarians (Manuila) - - -	40·2	0·000000	,,
2372 Roumanians fr. mountains	and	1272 Roumanians fr. valleys (Popoviciu)	15·2	0·0018	,,
213 Armenians (Parr)	and	380 Armenians (Kossowitsch) - -	18·5	0·00036	,,
653 Armenians (Altounyan)	and	380 Armenians (Kossowitsch) - -	16·5	0·0009	,,
1161 Japanese fr. Nagoya (Kawaishi & Furuhata).	and	1002 Japanese fr. Hida (Kawaishi & Furuhata).	75·4	0·000000	,,
1786 Japanese fr. Niigata (Miyaji)	and	1002 Japanese fr. Hida (Kawaishi & Furuhata).	34·9	0·000001	,,
205 Ainu (Ninomiya)	and	196 Ainu (Nakajima) - - - - -	26·9	0·000006	,,
501 Sanal Moros-Philippines (Grove)	and	442 Sulu Moros Philippines (Grove) -	44·7	0·000000	,,
933 Arabs (Altounyan)	and	500 Arabs (H. & H.) - - - - -	9·0	0·029	,,
500 Senegalese (H. & H.)	and	500 American Negroes (Snyder) -	12·3	0·006	,,
546 Sumatrans in Padang (Bais & Verhoef).	and	753 Melanesians in New Guinea (Heydon & Murphy).	31·8	0·000001	,,
500 Senegalese (H. & H.)	and	753 Melanesians (H. & H.) - - -	34·5	0·000000	,,
543 Swiss (Plüss)	and	1679 Germans fr. Schleswig-Holstein (Schütz & Wohlisch).	10·8	0·012	,,
500 Swedes (Lindberger)	and	500 Italians (H. & H.) - - -	22·9	0·00004	,,
500 Serbians (H. & H.)	and	500 Italians (H. & H.) - - -	10·2	0·0045	,,
500 Serbians (H. & H.)	and	1391 Italians (Mino) - - - -	24·4	0·00002	,,
500 Serbians (H. & H.)	and	500 Swedes (Lindberger) - - -	12·5	0·0059	,,
1679 Germans in Schleswig-Holstein (Schütz & Wohlisch).	and	500 Swedes (Lindberger) - - -	22·2	0·00006	,,
11488 Poles (Halber & Mydlarski)	and	9337 Japanese—Aggregate of data -	11·02	0·012	,,
500 Arabs (H. & H.)	and	5000 Americans (Culpepper) - -	10·51	0·0151	,,
1500 Hungarians (Vérzar & Weczeczky).	and	9337 Japanese - - - - - -	13·39	0·0037	,,
2200 Russians fr. Moscow (Wagner)	and	1500 Chinese (Li-Chi-Pau) - - -	15·40	0·0015	,,
5000 Americans (Culpepper)	and	500 American Negroes - - -	18·88	0·003	,,
818 Polish Jews (Halber & Mydlarski).	and	230 German Jews (Schiff & Ziegler) -	10·34	0·0165	,,
818 Polish Jews (H. & H.)	and	211 Roumanian Jews (Manuila) - -	12·40	0·0063	,,
818 Polish Jews (H. & H.)	and	500 Spanish Jews (H. & H.) - -	18·25	0·0004	,,
230 German Jews (Schiff & Ziegler)	and	211 Roumanian Jews—School children in Roumania (Manuila).	25·32	0·000014	,,
230 German Jews (Schiff & Ziegler)	and	500 Spanish Jews (H. & H.) - -	14·07	0·0028	,,
500 Spanish Jews—in Monastir (H. & H.).	and	211 Roumanian Jews (Manuila) - -	26·23	0·000009	,,

* The peoples compared are only considered to be significantly differentiated in their blood group distributions when *P* falls below a value of 0·05 or 1 in 20.

To the ordinary observer, the distributions in the Poles and Japanese and the Russians and Chinese respectively may be considered as practically identical and might be assumed to indicate that Poles were of the same racial type as Japanese and Russians as Chinese. Owing to the relatively large numbers on which these percentage distributions are based, however, the differences are greater than might reasonably be expected to arise from random sampling, as may be shown from values of $\chi^2 = 11 \cdot 02$ and $P = 0 \cdot 012$ in the first instance and $\chi^2 = 15 \cdot 40$ and $P = 0 \cdot 0015$ in the other. The respective pairs are differentiated in respect of their blood groups, but this conclusion depends on the relatively large numbers of observations. The principal Japanese data have been combined to obtain more adequate numbers, but, by this procedure, differences in the distributions in the several districts of Japan already described and emphasised by Japanese writers have been obscured, and yet it cannot be assumed that these divergencies may not be of some importance. It may be mentioned, further, that there is very grave doubt as to whether the records of certain observers are reliable or truly comparable with others, but to what extent this defect may be due to variations in technique or other causes, it is difficult to offer an opinion.

As it is impossible to decide upon which comparisons of pairs should be included as belonging to groups of similar race in order to calculate percentages of "successes" and "failures" in groups of like and unlike races—a procedure kindly suggested to me by Professor Greenwood—it has been considered sufficient to publish the values of χ^2 and P that have been obtained from comparisons of the blood group distributions in many pairs of population samples derived from the recent literature on the subject. These are given in detail in Table I. Many of these are from samples of the same or closely related peoples and the number of instances in which these samples appear differentiated with respect to blood group distribution whereas groups, racially dissimilar by almost every canon hitherto recognised, apparently agree in blood grouping within the limits of random sampling, should be sufficient to convince the most ardent supporters of blood grouping as a criterion of racial type or racial relationship that it may not be of such importance in this sphere as they anticipate.

I am indebted to Professor Elliot Smith for the suggestion that a study of the racial aspect of blood grouping might prove of value.

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MATTHEW YOUNG.

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THE INTERRELATIONSHIPS OF THE PHYSICAL MEASUREMENTS AND THE VITAL CAPACITY.

by

Matthew Young M.D.

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by

Matthew Young.

The relationships that exist between the several measurements of the human frame and between these and the vital capacity have long been a subject of interest. Various attempts have been made, since Hutchinson's pioneer work on the vital capacity, to construct formulae which would define in a simple form these relationships either as an aid to the diagnosis of disease or to the study of nutrition or for other purposes. Amongst those, with whose names such formulae are associated, are Pfaundler, Von Pirquet, Lissauer, Bornhardt, Ainley Walker and Dreyer. Professor Dreyer* has contributed largely to the subject. He has calculated formulae which are alleged to define in a simple manner the association between the several pairs of measurements of the human body and their individual relationship to vital capacity in his investigation into the latter as a criterion of physical fitness. He has also published an interesting series of tables, based on his formulae, showing the normal in one measurement for varying values of the others. These formulae were derived originally from a relatively small number of observations, though their

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*Dreyer, Georges (1920). The assessment of Physical Fitness. Cassell and Co.

Idem. (1919). "Investigations on the normal vital capacity in man and its relation to the size of the body." The Lancet, August 9th.

suitability appeared to be confirmed by the results obtained in longer series of data, namely, Hutchinson's and Schuster's, to which they were applied. There still seems to be, however, very considerable doubt as to whether one formula can be applied to define, with a sufficient degree of accuracy for general and practical use, the relationships between any pair of physical measurements or between these and vital capacity throughout the whole course of life as claimed by Professor Dreyer. Further investigation in large series of cases seems necessary and desirable to substantiate or disprove such an assertion before his formulae and tables come into wider and more general use by other observers, or gain general acceptance as providing more than a rough method of approximation.

Material used. While the data on which the present inquiry was made were chiefly obtained from the boys of Manchester Grammar School, frequent reference will also be made to results calculated from figures for adults published by Arnold* and figures for boys and adults kindly supplied for analysis by Dr Hobson.

Full details were available for about 1100 boys of the Grammar School of ages ranging from 11 to 19 years. In taking the measurements, the methods and instructions of Professor Dreyer were carefully followed in estimating the stem length, the chest circumference and the vital capacity. In regard to the weight, however, the method in use at Oxford was not accurately followed. At first it was decided to obtain the weights without clothes, but this method proved inconvenient and the weights were ultimately taken in the ordinary gymnasium costume. This has been found, after frequent estimates, to weigh very constantly between

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* Arnold, Friedrich (1855). Uber die Athmungsgrosse des Menschen, Heidelberg.

4 and 5 per cent. of the body weight for all ages. While it is recognised that weights in the nude condition are more reliable and desirable for comparative purposes, the weights as they have been taken should not impair to any appreciable extent or render invalid the results that have been obtained or vitiate the conclusions that have been drawn from them.

The data that were utilised, of those available in the case of each boy, were the exact age in years and months, the standing height, the stem length or trunk length, the weight, the chest circumference and the vital capacity. While the interrelationships of these variables have been considered generally in the present investigation, special attention has been directed to the relationship shown between the two measurements of length - viz., full and stem, - and body weight and vital capacity respectively.

The mean values of the measurements under consideration with their standard deviations and coefficients of variation for the boys at the several ages and for all ages together are shown in Table 1. One of the most striking features is the relatively wide range of variation that is met with in vital capacity and weight even in boys of the same age. The high degree of variation to which the latter measurement is subject has already been noted in other data by several observers and is now well known. The values of the coefficients of variation for full stature and stem length seem to indicate quite clearly that full stature is not more variable than stem length although this has been frequently suggested and has been used as an argument in favour of the use of the latter measurement in preference to the former.

<u>Correlation shown in Data</u>. It was decided to determine what relationships would be shown to exist between the

TABLE I.

Manchester Grammar School Data. Mean Values.

Age	Number of Observations	Standing Height			Stem Length			Vital Capacity			Weight			Chest Circumference		
		Mean cm.	S. D. cm.	C.	Mean cm.	S. D. cm.	C.	Mean c.c.	S. D. c.c.	C.	Mean kilog.	S. D. kilog.	C.	Mean cm.	S. D. cm.	C.
11 years	29	141·00	5·15	3·60	72·71	2·37	3·26	2155	266·40	12·36	33·12	3·47	10·48	65·66	2·98	4·54
12 „	112	145·86	8·03	5·51	74·45	3·83	5·14	2420	397·20	16·41	35·55	5·24	14·74	66·31	3·80	5·73
13 „	173	150·60	7·98	5·30	76·58	3·65	4·77	2578	465·90	18·07	40·14	6·30	15·70	69·44	4·08	5·88
14 „	255	156·97	8·97	5·71	79·81	4·47	5·60	2857	513·30	17·97	44·91	7·45	16·59	72·49	4·87	6·72
15 „	263	164·08	8·46	5·16	83·59	4·41	5·28	3268	573·00	17·53	50·30	7·42	14·75	76·24	5·23	6·86
16 „	173	167·81	8·31	4·95	85·79	4·54	5·29	3506	627·50	17·90	54·76	8·01	14·63	78·74	5·09	6·46
17 „	80	170·42	6·29	3·69	88·00	3·56	4·05	3713	678·30	18·27	57·30	7·22	12·60	81·01	4·63	5·72
18 „	25	171·66	7·66	4·46	89·00	4·08	4·56	4207	674·00	16·02	60·42	7·04	11·65	82·62	4·28	5·18
All ages	1110	159·04	11·75	7·39	81·21	6·16	7·59	3022	721·80	23·88	46·81	10·01	21·38	73·83	6·70	9·07

S. D. = standard deviation. C. = coefficient of variation.

TABLE II.

Manchester Grammar School Data. Total Correlation Coefficients.

Variables	11 years (29)	12 years (112)	13 years (173)	14 years (255)	15 years (263)	16 years (173)	17 years (80)	18 years (25)	12—17 years Mean value	All ages (1110)
Weight and standing height ...	·789 ± ·047	·748 ± ·028	·788 ± ·019	·774 ± ·017	·823 ± ·013	·812 ± ·017	·704 ± ·038	·784 ± ·052	·787	·897 ± ·004
Weight and stem length ...	·967 ± ·008	·709 ± ·032	·754 ± ·022	·819 ± ·014	·830 ± ·013	·749 ± ·023	·760 ± ·032	·718 ± ·065	·783	·901 ± ·004
Weight and vital capacity ...	·395 ± ·106	·635 ± ·038	·760 ± ·022	·693 ± ·022	·785 ± ·016	·736 ± ·024	·590 ± ·049	·778 ± ·053	·720	·851 ± ·006
Standing height and vital capacity	·457 ± ·099	·578 ± ·042	·732 ± ·024	·733 ± ·020	·718 ± ·020	·682 ± ·027	·577 ± ·050	·715 ± ·066	·692	·835 ± ·006
Stem length and vital capacity...	·234 ± ·118	·551 ± ·044	·788 ± ·019	·733 ± ·020	·683 ± ·022	·674 ± ·028	·566 ± ·051	·783 ± ·052	·688	·836 ± ·006
Standing height and stem length	·490 ± ·095	·853 ± ·017	·878 ± ·012	·886 ± ·009	·825 ± ·013	·851 ± ·014	·808 ± ·026	·822 ± ·044	·854	—
Standing height and chest circumference ...	·225 ± ·119	·652 ± ·037	·670 ± ·028	·651 ± ·024	·688 ± ·022	·651 ± ·030	·507 ± ·056	·373 ± ·116	·653	·836 ± ·006
Stem length and chest circumference ...	·421 ± ·103	·716 ± ·031	·646 ± ·030	·710 ± ·021	·718 ± ·020	·669 ± ·028	·629 ± ·045	·487 ± ·103	·689	·835 ± ·006
Vital capacity and chest circumference ...	·419 ± ·103	·550 ± ·044	·698 ± ·026	·699 ± ·025	·742 ± ·019	·694 ± ·027	·688 ± ·040	·552 ± ·094	·692	·831 ± ·006
Weight of body and chest circumference ...	·701 ± ·064	·881 ± ·014	·855 ± ·013	·877 ± ·010	·891 ± ·009	·868 ± ·013	·840 ± ·022	·780 ± ·053	·873	·936 ± ·002

TABLE III.

Partial Correlation Coefficients. Boys of all Ages.

	Vital capacity and standing height	Vital capacity and stem length	Vital capacity and chest girth	Vital capacity and weight	Vital capacity and age	Standing height and chest girth	Stem length and chest girth
Total Coefficients ...	835· ± ·006	·836 ± ·006	·831 ± ·006	·851 ± ·006	·662 ± ·011	·836 ± ·006	·835 ± ·006
Partial Coefficients							
(First Order)							
Standing height constant	—	—	·441 ± ·016	·419 ± ·017	·171 ± ·020	—	—
Stem length constant ...	—	—	·440 ± ·016	·411 ± ·017	·148 ± ·020	—	—
Chest constant	·459 ± ·016	·464 ± ·016	—	·374 ± ·017	·188 ± ·020	—	—
Weight constant... ...	·310 ± ·018	·304 ± ·018	·184 ± ·020	—	·175 ± ·020	− ·026 ± ·020	− ·054 ± ·020
Vital capacity constant...	—	—	—	—	—	·464 ± ·016	·460 ± ·016
Age constant	·690 ± ·011	·690 ± ·011	·684 ± ·011	·724 ± ·009	—	·669 ± ·011	·661 ± ·011
(Second Order)							
Standing height and chest constant	—	—	—	·140 ± ·020	·051 ± ·020	—	—
Stem length and chest constant	—	—	—	·126 ± ·020	·034 ± ·020	—	—
Standing height and weight constant ...	—	—	·206 ± ·019	—	·099 ± ·020	—	—
Stem length and weight constant	—	—	·213 ± ·019	—	091 ± ·020	—	—
Standing height and age constant	—	—	·416 ± ·017	·399 ± ·017	—	—	—
Stem length and age constant	—	—	·420 ± ·017	·397 ± ·017	—	—	—
Chest and weight constant	·318 ± ·018	·320 ± ·018	—	—	·182 ± ·020	—	—
Chest and age constant...	·429 ± ·017	·433 ± ·016	—	·355 ± ·018	—	—	—
Weight and age constant	·271 ± ·019	·267 ± ·019	·155 ± ·020	—	—	− ·087 ± ·020	− ·125 ± ·020
Standing height and vital capacity constant	—	—	—	—	—	—	—
Stem length and vital capacity constant	—	—	—	—	—	—	—
Chest and vital capacity constant	—	—	—	—	—	—	—
Weight and vital capacity constant	—	—	—	—	—	− ·086 ± ·020	− ·119 ± ·020
Age and vital capacity constant	—	—	—	—	—	·371 ± ·018	·358 ± ·018
(Third Order)							
Standing height, chest and weight constant	—	—	—	—	·058 ± ·020	—	—
Stem length, chest and weight constant	—	—	—	—	·043 ± ·020	—	—
Standing height, chest and age constant	—	—	—	·143 ± ·020	—	—	—
Stem length, chest and age constant	—	—	—	·129 ± ·020	—	—	—
Standing height, weight and age constant	—	—	·190 ± ·020	—	—	—	—
Stem length, weight and age constant	—	—	·198 ± ·020	—	—	—	—
Standing height, age and vital capacity constant	—	—	—	—	—	—	—
Stem length, age and vital capacity constant	—	—	—	—	—	—	—
Chest, weight and age constant	·293 ± ·019	·292 ± ·019	—	—	—	—	—
Weight, vital capacity and age constant	—	—	—	—	—	− ·133 ± ·020	− ·174 ± ·020
Chest, vital capacity and age constant	—	—	—	—	—	—	—

TABLE III (*continued*).

	Standing height and weight	Stem length and weight	Weight and chest girth	Standing height and age	Stem length and age	Chest girth and age	Weight and age
Total Coefficients ...	·897 ± ·004	·901 ± ·004	·936 ± ·003	·714 ± ·010	·725 ± ·010	·708 ± ·010	·701 ± ·010
Partial Coefficients							
(*First Order*)							
Standing height constant	—	—	·767 ± ·008	—	—	—	—
Stem length constant ...	—	—	·770 ± ·008	—	—	—	—
Chest constant	·595 ± ·013	·617 ± ·013	—	—	—	—	—
Weight constant... ...	—	—	—	—	—	—	—
Vital capacity constant...	·644 ± ·012	·658 ± ·012	·783 ± ·008	—	—	—	—
Age constant	·794 ± ·008	·800 ± ·007	·873 ± 005	—	—	—	—
(*Second Order*)							
Standing height and chest constant	—	—	—	—	—	—	—
Stem length and chest constant	—	—	—	—	—	—	—
Standing height and weight constant ...	—	—	—	—	—	—	—
Stem length and weight constant	—	—	—	—	—	—	—
Standing height and age constant	—	—	·757 ± ·009	—	—	—	—
Stem length and age constant	—	—	·764 ± ·008	—	—	—	—
Chest and weight constant	—	—	—	—	—	—	—
Chest and age constant...	·583 ± ·013	·607 ± ·013	—	—	—	—	—
Weight and age constant	—	—	—	—	—	—	—
Standing height and vital capacity constant	—	—	·716 ± ·010	—	—	—	—
Stem length and vital capacity constant	—	—	·719 ± ·010	—	—	—	—
Chest and vital capacity constant	·513 ± ·015	·540 ± ·014	—	—	—	—	—
Weight and vital capacity constant	—	—	—	—	—	—	—
Age and vital capacity constant	·588 ± ·013	·601 ± ·013	·752 ± ·009	—	—	—	—
(*Third Order*)							
Standing height, chest and weight constant	—	—	—	—	—	—	—
Stem length, chest and weight constant	—	—	—	—	—	—	—
Standing height, chest and age constant	—	—	—	—	—	—	—
Stem length, chest and age constant	—	—	—	—	—	—	—
Standing height, weight and age constant	—	—	—	—	—	—	—
Stem length, weight and age constant	—	—	—	—	—	—	—
Standing height, age and vital capacity constant	—	—	·711 ± ·010	—	—	—	—
Stem length, age and vital capacity constant	—	—	·717 ± ·010	—	—	—	—
Chest, weight and age constant	—	—	—	—	—	—	—
Weight, vital capacity and age constant	—	—	—	—	—	—	—
Chest, vital capacity and age constant	·505 ± ·015	·537 ± ·014	—	—	—	—	—

several pairs of measurements in the data by the method of correlation as a preliminary to further investigation by Professor Dreyer's methods. The correlation coefficients were thus calculated between the several pairs of measurements for all the boys taken together, irrespective of age, and for the groups of boys at each age. These coefficients are shown in Table II, with the numbers at each age on which the calculations are based. The numbers at ages 11 and 18 are comparatively small and the coefficients at these ages, though calculated and inserted in the table, as they are less reliable than the others, have been disregarded in the formulation of any conclusions from the values obtained. As a general index of comparison of the degree of correlation between the several pairs of measurements, the mean values of the coefficients for the different ages from 12 to 17 should be taken rather than the coefficients for all the boys grouped together. The latter coefficients are appreciably higher than the mean values of the corresponding coefficients found for boys at the several ages which is probably largely due to the circumstance that each of the two variables is quite definitely positively correlated with increase of age, as considerable growth in all dimensions takes place in this age period and this correlation is not allowed for in calculating the total coefficients for all ages together. The correlation coefficients between the several dimensions and increasing age by half years were determined later to show how each increases with advancing age. They are shown in the first row of Table III. Knowing these values it was possible to calculate the partial correlations that existed between the several pairs of dimensions under consideration when age was assumed to remain constant (Table III). This procedure results in coefficients which are appreciably less in value than those determined for the corresponding pairs of dimensions irrespective of age, thus confirming the suggestion, made above, that varying age exerts an appreciable influence in determining the magnitude of the latter coefficients.

In reviewing the values of the coefficients of correlation, as they are presented in Table II, several points of interest become evident. The coefficients between any two variables seem to show definite, if not significant, differences at the several ages. This is marked even when the coefficients for ages 11 and 18 are excluded owing to the paucity of observations on which they are based. While there is no very definite evidence that they vary at the different ages in any special or characteristic manner it seems more than a coincidence that, with one or two exceptions, the highest values are attained at ages 13 to 15*. This relationship seems to merit further investigation. The highest correlation found is that between weight of body and chest circumference which just exceeds in value that between standing height and stem or trunk length. One notable feature is the relative degree of association shown between the standing height and stem length respectively and the other variables. The correlation coefficients between standing height and weight and stem length and weight are practically identical, and the same holds for standing height and vital capacity and stem length and vital capacity and also for standing height and chest circumference and stem length and chest circumference. The full stature measurement has recently fallen into disrepute and there has been a tendency,

* The mean coefficients for all characters run

Age	12	13	14	15	16	17
Mean coefficient	·6873	·7569	·7575	·7703	·7386	·6669

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for various theoretical reasons, to discard it practically as being a measurement of no great significance in relation to other body measurements. It has been suggested that, as compared with the stem length, full stature is an "impure measure" owing to the varying angle of the neck of the femur, varying spinal curvature, varying compression of the intervertebral discs, varying thickness and turgescence of the soft tissues in the scalp and soles, deformities or defective growth in the leg bones and other causes, while it has been asserted confidently by recent workers on the subject that no simple relationship can be found to exist between standing height and various other body measurements, including vital capacity, while such a relationship can be demonstrated between these measurements and stem length. The values in Table II show, however, that, so far as a conclusion can be drawn for the period of life covered by the age of these boys, the standing height is in all respects as closely related to weight, to chest girth and to vital capacity as the stem length. The very close similarity in the relationships of standing height and stem length respectively to vital capacity is shown more precisely by the values of the partial correlation coefficients of the different orders between the variables when the age and other measurements are assumed to remain constant. These are shown in the first two columns of Table III. It is evident that the corresponding values of the coefficients in the two cases are practically identical. Further proof of this similarity in relationship will be furnished later. Table II shows also the degree of correlation existing between body weight and chest girth respectively and vital capacity. It is seen that, of the measurements that have been taken, body weight is most highly correlated with the vital capacity, the magnitude of this correlation even exceeding slightly, though perhaps not to a significant degree, the value shown for that between chest girth and vital capacity. While the last two dimensions show a well marked correlation, increase of chest circumference being closely related on the average to increased vital capacity, yet the higher value shown in the correlation coefficient between weight and vital capacity would appear to indicate to what an extent in the growing boy the magnitude of the record of the spirometer is dependent on the increase of body weight. Increased weight implies vigour and power to expel the air from the chest, and this appears to be as important in determining a better vital capacity as variation in the actual size of the chest. This view seems to be supported by the circumstance that the partial correlation between weight and vital capacity, when the chest girth is assumed to remain constant is distinctly higher than that between the chest circumference and vital capacity with constant weight, the values being 0.374 and 0.184 respectively (Table III). In the partial correlations of the highest order, however, the position is reversed. Chest girth appears to be more highly correlated with vital capacity than is weight when all the other variables are assumed to remain constant. The difference is slight, and the balance in favour of chest girth cannot be regarded as of practical significance. The correlation that exists between the weight-height ratio and increasing age in half years has also been calculated. The value of the coefficient is 0.630, which is certainly significant and indicates that, with advancing years during the period of adolescence, weight definitely increases relatively to height.

Regression Equations. The correlation ratios between weight and stem length, weight and full stature, weight and vital capacity, full stature and vital capacity, stem length and vital capacity and between these several measurements and age were calculated and are shown in Table IV. The values of $\frac{\sqrt{N}}{.67449}\ \frac{1}{2}\sqrt{\zeta}$, the approximate test used, seemed to indicate that, within the range of observation, there was not in the case of any of the variates, with the exception of full stature, any very marked departure from linearity of regression on age. The regression of full stature on age is known to be non-linear. In regard to the regression on the other measurements full stature also shows the greatest departure from linearity. Graphs were drawn (Diagrams 1 - 5) showing the regression straight line in relation to

TABLE IV.

Manchester Grammar School Data. Correlation Ratios.

Showing Deviation from Linearity in Regression Lines.

Variables	Correlation ratio η	Correlation coefficient r	$\eta^2 - r^2$ (ζ)	$\frac{\sqrt{N}}{\cdot 67449}\ \frac{1}{2}\sqrt{\zeta}$
Weight on age	·709	·702	·011280	2·63
Vital capacity on age ...	·669	·662	·009317	2·37
Full stature on age	·726	·714	·017280	3·25
Stem length on age	·733	·725	·011664	2·67
Chest girth on age	·715	·708	·009961	2·47
Weight on full stature ...	·902	·897	·008995	2·35
Full stature on weight ...	·908		·019855	3·50
Weight on stem length ...	·904	·901	·005415	1·82
Stem length on weight ...	·907		·010848	2·58
Vital capacity on weight ...	·855	·851	·006824	2·03
Weight on vital capacity ...	·863		·020568	3·53
Vital capacity on full stature	·841	·835	·010056	2·47
Full stature on vital capacity	·855		·033800	4·53
Vital capacity on stem length	·839	·836	·005025	1·75
Stem length on vital capacity	·851		·025305	3·92

the means of the arrays for each of the five measurements on age. The straight lines seem to give a reasonably good fit except at the extremities of the range where the mean values of the arrays are based on a very few observations. The "goodness of fit" test gives the following values:

	χ^2	P
Weight on age	25·929	·102
Vital capacity on age ...	24·647	·136
Chest on age	21·920	·236
Stem length on age ...	31·420	·036
Full stature on age ...	39·721	·002

indicating clearly that the fits obtained for stem length and full stature are not good when all the observations are included. As the appearance of the graph for full stature on age suggested that the deviations were not random and that a better fit would be obtained by fitting a cubic parabola to the data, this was done for each of the measurements. In each case the value at age 10.25 was excluded to obtain an uneven number of observations. The cubic equations calculated are shown in the Diagrams 1 - 5 and the fits obtained are indicated by the interrupted lines. The accuracy of the fit obtained by the cubic equation may be compared with that obtained by linear regression in the several cases by tabulating the root-mean-square deviations obtained from the corresponding 17 observations.

	Cubic parabola	Regression straight line (omitting first observation)
Vital capacity on age ...	85·55 c.c.	89·20 c.c.
Weight on age	1·05 kilog.	1·38 kilog.
Stem length on age ...	·44 cm.	1·17 cm.
Chest girth on age ...	·58 cm.	1·05 cm.
Full stature on age ...	·95 cm.	2·18 cm.

The cubic equation thus apparently gives a decidedly better fit than the regression line and the improvement is greatest in the two measurements of length. As the regression lines seemed to give moderately good fits except at the extreme ages the coefficients of regression and regression equations were determined for the several pairs of variables. These equations are shown in Table V, with the standard errors (or root-mean-square errors) made in using them. The coefficients of regression show the change in one variable that is associated on the average with unit change in the other and from the equations the average values of one variable can be predicted from a knowledge of the values of the other. It is interesting to note that the regression coefficient between standing height and vital capacity (changed to inches and cubic inches),

TABLE V. *Manchester Grammar School Data. Regression Formulae.*

			Standard error of regression equation	Percentage error
1	All ages	$X_1 = 97{\cdot}8636 X_2 - 4922{\cdot}8322$	396·9 c.c.	13·13
2	,,	$X_1 = 51{\cdot}3839 X_0 - 5148{\cdot}4497$	397·1 c.c.	13·14
3	,,	$X_1 = 61{\cdot}4204 X_3 + 148{\cdot}1111$	379·4 c.c.	12·55
4	,,	$X_1 = 89{\cdot}6538 X_4 - 3590{\cdot}0781$	401·3 c.c.	13·28
5	,,	$X_1 = 21{\cdot}65 X_0 + 18{\cdot}00 X_3 + 29{\cdot}63 X_4 + 19{\cdot}47 X_5 - 3740{\cdot}67$	352·5 c.c.	11·66
6	,,	$X_1 = 42{\cdot}71 X_2 + 16{\cdot}60 X_3 + 31{\cdot}16 X_4 + 14{\cdot}57 X_5 - 3741{\cdot}03$	352·5 c.c.	11·66
7	Age 12	$X_1 = 23{\cdot}58 X_2 + 45{\cdot}09 X_3 - 14{\cdot}16 X_4 + {\cdot}48$	301·0 c.c.	12·44
8	,, 13	$X_1 = 63{\cdot}75 X_2 + 17{\cdot}48 X_3 + 20{\cdot}00 X_4 - 4394{\cdot}73$	258·0 c.c.	10·01
9	,, 14	$X_1 = 58{\cdot}95 X_2 - 6{\cdot}24 X_3 + 43{\cdot}98 X_4 - 4755{\cdot}29$	323·0 c.c.	11·31
10	,, 15	$X_1 = 15{\cdot}22 X_2 + 37{\cdot}86 X_3 + 24{\cdot}26 X_4 - 1757{\cdot}69$	349·0 c.c.	10·68
11	,, 16	$X_1 = 37{\cdot}43 X_2 + 27{\cdot}81 X_3 + 24{\cdot}96 X_4 - 3193{\cdot}03$	404·0 c.c.	11·52
12	,, 17	$X_1 = 56{\cdot}00 X_2 - 17{\cdot}68 X_3 + 97{\cdot}09 X_4 - 8066{\cdot}99$	475·0 c.c.	12·79
13	All ages	$X_3 = 1{\cdot}4643 X_2 - 72{\cdot}0369$	4·36 klg.	9·31
14	,,	$X_3 = {\cdot}7658 X_0 - 74{\cdot}9083$	4·43 klg.	9·46
15	,,	$X_3 = 1{\cdot}3974 X_4 - 56{\cdot}3204$	3·53 klg.	7·54

where X_1 = Vital capacity in cubic centimetres.
X_0 = Standing height in centimetres.
X_2 = Stem length in centimetres.
X_3 = Weight in kilogrammes.
X_4 = Chest girth in centimetres.
X_5 = Age in years.

TABLE VII.

Dr Hobson's Data and Arnold's Data.

Total and Partial Correlation Coefficients.

Variables	100 selected adults from police force	279 boys of Westminster School. Age 12–18 years	215 boys of L.C.C. School. Age 5–13 years	Arnold's data, 116 males. Age 17–30 years
	r	r	r	r
Standing height and weight ...	+0·428 ± ·055	+0·842 ± ·012	+0·944 ± ·005	·615 ± ·040
Stem length and weight	+0·341 ± ·060	+0·863 ± ·010	+0·908 ± ·008	—
Standing height and vital capacity	+0·292 ± ·062	+0·807 ± ·014	+0·878 ± ·011	·705 ± ·032
Stem length and vital capacity ...	+0·321 ± ·061	+0·827 ± ·013	+0·817 ± ·015	·593 ± ·041
Weight and vital capacity	+0·190 ± ·065	+0·843 ± ·012	+0·874 ± ·011	·524 ± ·046
Chest girth and vital capacity ...	+0·150 ± ·066	+0·849 ± ·011	+0·784 ± ·018	—
Chest girth and weight	+0·619 ± ·042	+0·917 ± ·006	+0·927 ± ·006	—
Standing height and stem length ...	+0·611 ± ·042	+0·917 ± ·006	+0·942 ± ·005	·723 ± ·030
Standing height and chest girth ...	+0·038 ± ·067	+0·780 ± ·016	+0·888 ± ·010	—
Stem length and chest girth ...	+0·155 ± ·066	+0·816 ± ·013	+0·849 ± ·013	—
Standing height and age	—	+0·630 ± ·024	+0·901 ± ·008	—
Stem length and age	—	+0·678 ± ·022	+0·822 ± ·015	—
Weight and age	—	+0·658 ± ·023	+0·865 ± ·012	—
Vital capacity and age	—	+0·669 ± ·022	+0·804 ± ·016	—
Chest girth and age	—	+0·664 ± ·023	+0·816 ± ·015	—
Weight-stem length ratio and age...	—	—	+0·850 ± ·012	—
Standing height and weight with age constant	—	+0·730 ± ·019	+0·760 ± ·019	—
Stem length and weight with age constant	—	+0·754 ± ·017	+0·689 ± ·026	—
Standing height and vital capacity with age constant	—	+0·669 ± ·022	+0·598 ± ·030	—
Stem length and vital capacity with age constant	—	+0·683 ± ·022	+0·461 ± ·036	—
Weight and vital capacity with age constant	—	+0·720 ± ·019	+0·601 ± ·029	—
Chest girth and vital capacity with age constant	—	+0·729 ± ·019	+0·373 ± ·039	—
Weight and chest girth with age constant	—	+0·853 ± ·011	+0·762 ± ·019	—
Stem length and chest girth with age constant	—	+0·666 ± ·022	+0·541 ± ·033	—
Standing height and vital capacity with weight constant	+0·238 ± ·064	—	—	·570 ± ·042
Weight and vital capacity with height constant	+0·075 ± ·067	—	—	·161 ± ·061

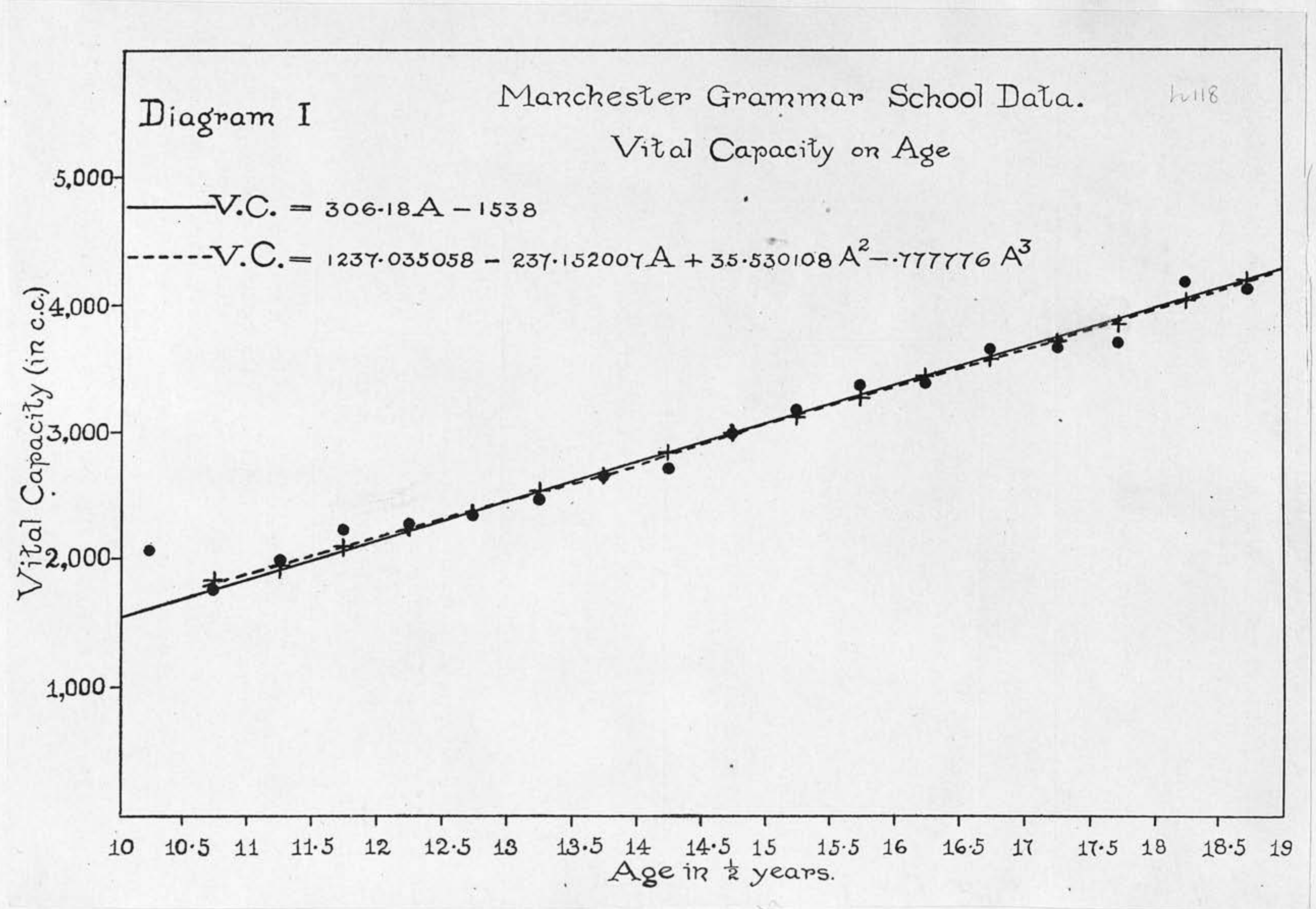
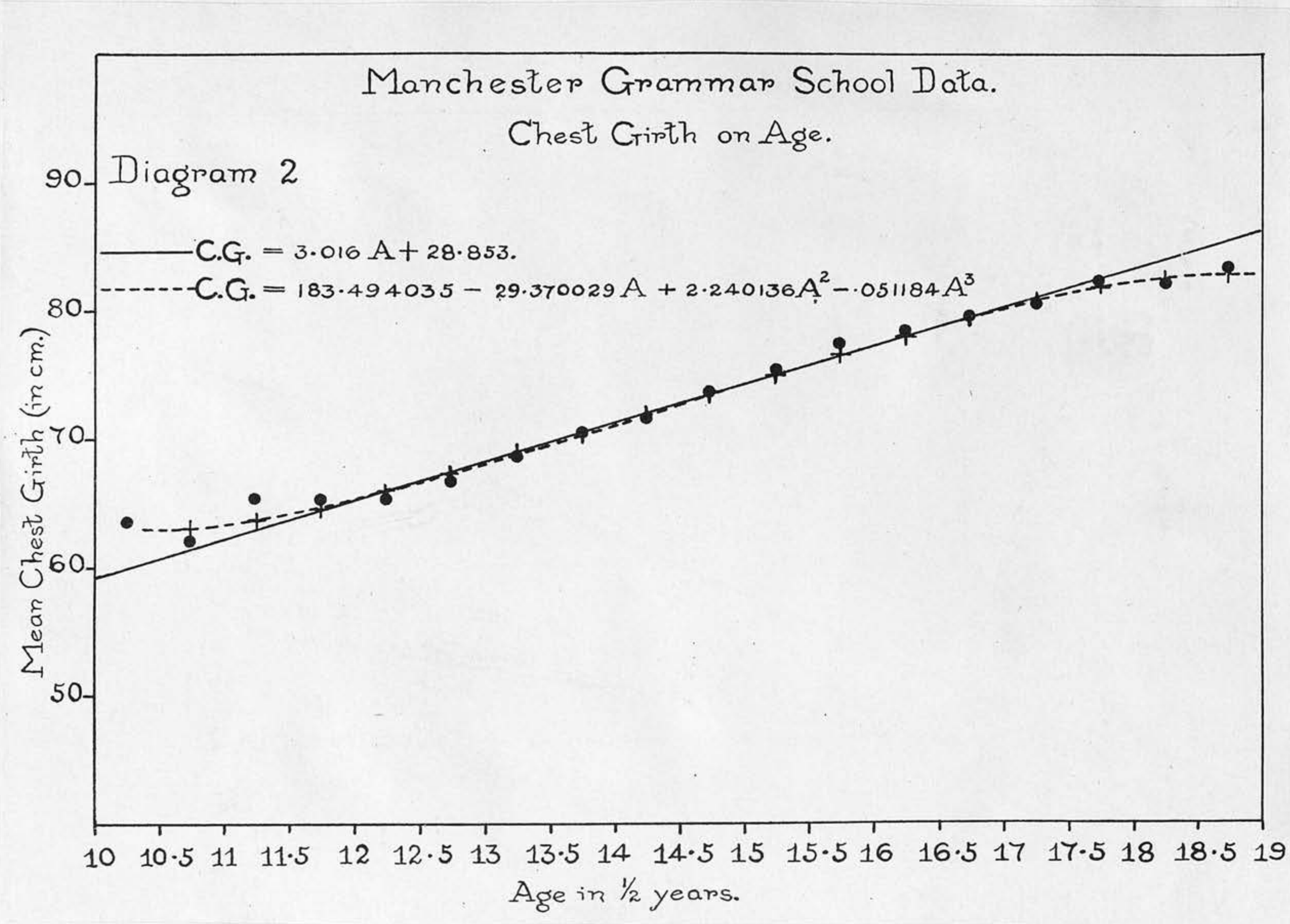


Diagram I
Manchester Grammar School Data.
Vital Capacity on Age
V.C. = 306·18A − 1538
V.C. = 1237·035058 − 237·152007A + 35·530108 A² − ·777776 A³
Vital Capacity (in c.c.)
5,000
4,000
3,000
2,000
1,000
10
10·5
11
11·5
12
12·5
13
13·5
14
14·5
15
15·5
16
16·5
17
17·5
18
18·5
19
Age in ½ years.
h118



Manchester Grammar School Data.
Chest Girth on Age.
Diagram 2
C.G. = 3·016 A + 28·853.
C.G. = 183·494035 − 29·370029 A + 2·240136 A² − ·051184 A³
Mean Chest Girth (in cm.)
90
80
70
60
50
10 10·5 11 11·5 12 12·5 13 13·5 14 14·5 15 15·5 16 16·5 17 17·5 18 18·5 19
Age in ½ years.

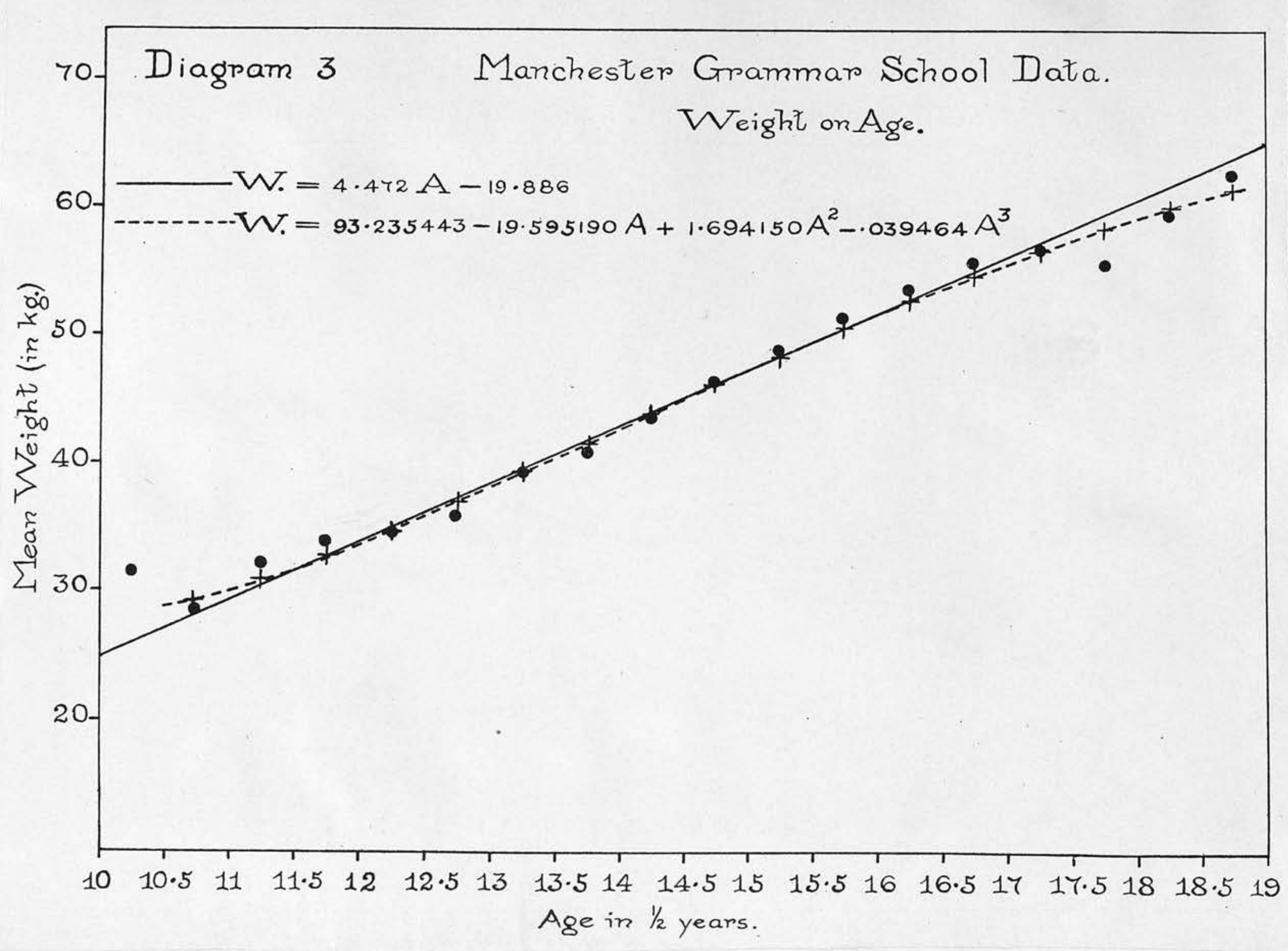
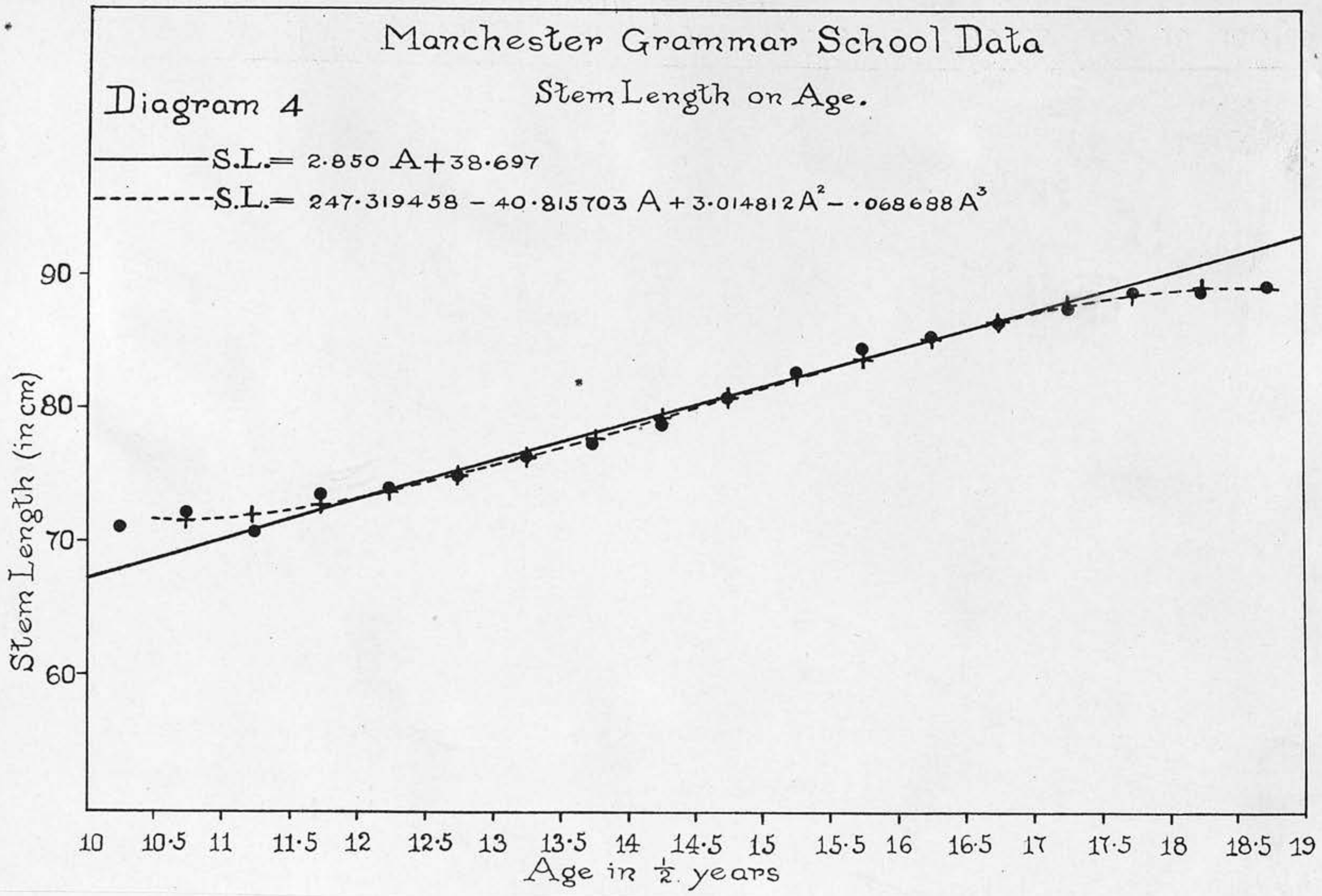


Diagram 3
Manchester Grammar School Data.
Weight on Age.
$W. = 4\cdot472\,A - 19\cdot886$
$W. = 93\cdot235443 - 19\cdot595190\,A + 1\cdot694150\,A^2 - \cdot039464\,A^3$
Mean Weight (in kg.)
70
60
50
40
30
20
10
10·5
11
11·5
12
12·5
13
13·5
14
14·5
15
15·5
16
16·5
17
17·5
18
18·5
19
Age in ½ years.


Manchester Grammar School Data
Diagram 4
Stem Length on Age.
S.L.= 2·850 A+38·697
S.L.= 247·319458 − 40·815703 A + 3·014812 A² − ·068688 A³
Stem Length (in cm)
60
70
80
90
10
10·5
11
11·5
12
12·5
13
13·5
14
14·5
15
15·5
16
16·5
17
17·5
18
18·5
19
Age in ½ years

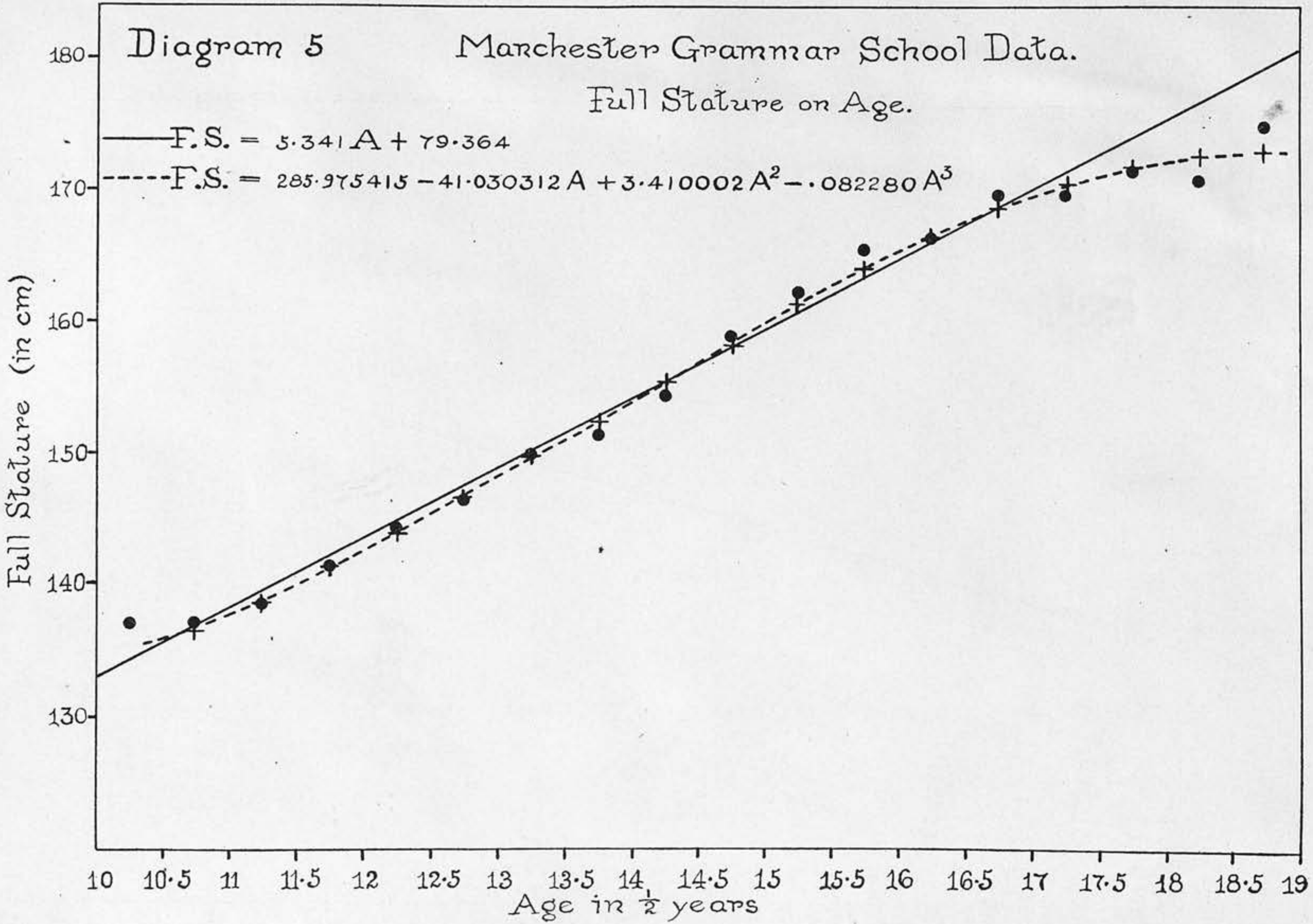


Diagram 5
Manchester Grammar School Data.
Full Stature on Age.
F.S. = 5·341 A + 79·364
F.S. = 285·975415 − 41·030312 A + 3·410002 A² − ·082280 A³
Full Stature (in cm)
180
170
160
150
140
130
10
10·5
11
11·5
12
12·5
13
13·5
14
14·5
15
15·5
16
16·5
17
17·5
18
18·5
19
Age in ½ years

calculated from the 1100 observations, indicates that for these boys, ranging in age from 11 to 18 years, an increase of one inch in height is associated on the average with an increase of 7.97 cubic inches in vital capacity, an unexpected confirmation of the conclusion arrived at by Hutchinson* so many years ago, but recently discredited, namely, that "for every inch of height (from 5-6 ft.) eight additional cubic inches of air at 60° are given out by a forced expiration." Hutchinson's dictum as to the occurrence of an increase in vital capacity of eight cubic inches with increase in height of one inch cannot be expected to hold from case to case with unfailing accuracy; it was only intended to be applicable to typical cases or to cases on the average. A similar relationship seems to obtain for adults; at least, it is shown in Arnold's data, to which further reference will be made later. In these the coefficients of regression of vital capacity on height is 51.58 c.c. for each cm. in height, which, converted into cubic inches and inches, indicates that for an increase of one inch in height there is, on the average, an increase of 7.99 cubic inches of vital capacity.

It is important to note the magnitude of the standard errors of the primary regression equations or standard deviations of the arrays shown in Table V. These are for boys of all ages and are seen to exceed 9 per cent, in estimating weight from stem length or full length, and 13 per cent, in estimating vital capacity from either stem length, full length or chest girth. For the groups of boys at each age from 12-17, not shown in the table, the standard deviations of weight arrays on stem length vary from 8 to 10.5 per cent., and of vital capacity arrays on weight from

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* Hutchinson, John (1846), "On the Capacity of the Lungs and on the Respiratory Functions, etc." Medico-Chirug.Trans. XXIX. London. Ibid. (1846), The Lancet, Vol. I.

11 to 14.5 per cent. In addition to these primary regression formulae, multiple regression formulae suitable for the prediction of vital capacity from the other measurements in the Grammar School boys were subsequently calculated. These give the vital capacity.

1. in terms of the stem length, chest girth, weight and age for boys at all ages;

2. in terms of the stem length, chest girth and weight for boys at each age from 12-17 years inclusive;

3. in terms of full stature, chest girth, weight and age for boys at all ages.

These formulae with the root-mean-square errors made in using them are also shown in Table V. It is evident that in thus predicting vital capacity from the partial regression equations including all the variables the average percentage errors remain still in excess of 10 per cent.

Correlation shown in other Data. It seemed desirable at this stage for the purposes of comparison and confirmation to inquire into the relationships that obtain between the corresponding measurements in data for the same and other periods of life. For that purpose, use was made of certain data which were kindly placed at our disposal by Dr. Hobson. These included the measurements of:

(a) 100 adults from the police force.

(b) 279 boys of ages 12-18 years from Westminster School.

(c) 215 boys of ages 5-13 years from the L.C.C. School, Ellerslie Road.

The mean values of the measurements in the respective groups with their standard deviations and coefficients of variation are shown in Table VI. The total and partial correlation coefficients that have been calculated for the data are also shown in Table VII. The correlations obtained between full length and stem length respectively

TABLE VI.

Dr Hobson's Data. Mean Values.

Data	Standing Height			Stem Length			Weight			Vital Capacity			Chest Girth			Age		
	Mean cm.	S. D. cm.	C.	Mean cm.	S. D. cm.	C.	Mean kilog.	S. D. kilog.	C.	Mean c.c.	S. D. c.c.	C.	Mean cm.	S. D. cm.	C.	Mean yrs	S. D. yrs	C.
Boys of L.C.C. School 5–13 years (215)	130·27	14·00	10·75	69·06	5·42	7·85	26·94	7·06	26·21	2000	486·20	24·31	61·99	5·20	8·39	10·19	2·64	25·91
Boys of Westminster School, 12–18 years (279)	168·48	10·18	6·04	85·16	5·78	6·79	52·90	9·80	18·53	3739	787·50	21·06	79·84	6·31	7·90	15·87	1·40	8·82
Selected adults from police force (100)	179·10	4·39	2·45	92·59	2·68	2·89	70·76	6·03	8·52	4823	492·00	10·20	88·92	4·20	4·72	—	—	—
Boys of Manchester Grammar School, 11–18 years (1100). For comparison with Westminster boys	159·04	11·75	7·39	81·21	6·16	7·59	46·81	10·01	21·38	3022	721·80	23·88	73·83	6·70	9·07	14·91	1·57	10·53

S. D. = standard deviation. C. = coefficient of variation.

and weight and vital capacity seem, on the whole, to support the conclusions drawn from the data for the boys of the Grammar School. In the boys of Westminster School, the correlation coefficients between stem length and the other two measurements appear to be slightly in excess of those shown between these and full length, but the differences are practically insignificant.

The standard deviations of the vital capacity array for the type of weight array and of the weight array for the type of stem length array have been calculated and are shown in Table VIII. For the two groups of boys, Westminster and

TABLE VIII.

Dr Hobson's Data.

Data	Standard deviation of weight arrays for stem length array			Standard deviation of vital capacity arrays for weight array		
	Mean weight in kilos.	S. D. of weight array in kilos.	Percentage S. D.	Mean V. C. in c.c.	S. D. of V. C. array in c.c.	Percentage S. D.
215 boys of L.C.C. School. Age 5–13 years	26·94	2·95	10·9	2000	236·2	11·8
279 boys of Westminster School. Age 12–18 yrs	52·90	4·95	9·4	3739	423·6	11·3
100 adults selected from the police force	70·76	5·67	8·0	4823	483·0	10·0

Ellerslie Road, the standard deviation of the vital capacity array is again in excess of 11 per cent., and that of weight exceeds 9 per cent. In the data for the group of adults belonging to the police force, the standard deviation of the vital capacity array is still as high as 10 per cent., and that of the weight array as high as 8 per cent. This shows the extent of variation in these two measurements that may be found even in such a carefully selected group of individuals.

For the later period of life, other data regarding the weight, the full stature, the stem length and the vital capacity were obtained from a paper publised in 1855 by Arnold who was familiar with Hutchinson's work on the respiratory functions and was apparently greatly influenced by it in the methods of pursuing his investigations. For a series of observations on 116 males ranging in age from 17 to 30 years it was found that the correlation between standing height and vital capacity was 0.705, that between stem length and vital capacity 0.593, while that between standing height and stem length was 0.723 (Table VII). In this group also there is, therefore, no evidence that stem length is more closely correlated with vital capacity than is full stature, thus confirming by a modern method of analysis Arnold's direct conclusion from the study of his observations that he could not agree that stem length was of more value than full stature in estimating vital capacity. The correlation coefficient between weight and vital capacity was 0.524, and that between weight and height 0.615. The partial correlation between height and vital capacity when weight was assumed to remain constant was 0.570, while that between weight and vital capacity when height was constant was only 0.161, from which it would appear that in adults vital capacity is in closer relationship to full stature than to weight. In the data for the 100 adults selected from the police force, the correlation between height and vital capacity is also definitely higher than that between weight and vital capacity. This difference is brought out more clearly by the partial correlation coefficients. It will be recalled that the total correlations obtained for the Grammar School boys examined seemed to suggest that of the two measurements - weight and height - the former was at least as closely associated with vital capacity as the latter. This appeared to be confirmed for other boys at the same age period by the correlations found in the data for Westminster School (Table VII). The partial correlation coefficients of the highest order show, however, that in the boys, as in adults, when all the other measurements are constant, height is more closely correlated with vital capacity than is weight. In this connexion it is worthy of note that Arnold concluded from his observations on adults that weight was to be considered in relation to vital capacity only in so far as it was influenced by height.

Weight-length Relationship shown by Power Formulae. We now come to consider the relation of stem length and standing height to weight as shown by a formula of the type proposed by Dr Ainley Walker and Professor Dreyer.

It is of the form:

$$l = kw^n,$$

where l = length, stem or full, in centimetres: w = weight in kilogrammes: and k is a constant.

From the series of weights and heights, in the Grammar School data, the values of n and k were calculated by the method of least squares for the boys in each age group and for all ages taken together. The results are set out in Table IX.

TABLE IX.

Manchester Grammar School Data.

Formula: $l = kw^n$.

Age group	Standing height and weight		Stem length and weight	
	n_1	k_1	n_2	k_2
11 years	·279	53·120	·213	34·502
12 "	·278	54·059	·251	30·402
13 "	·269	55·942	·245	31·090
14 "	·280	54·251	·284	28·377
15 "	.284	54·140	·306	25·288
16 "	·281	54·543	·289	27·029
17 "	·226	68·349	·282	28·131
18 "	·291	52·099	·279	28·364
All ages (weighted observations)	·310	48·467	·315	24·261
All ages (weight in grammes)...	·310	5·6944	·315	2·7536
All ages (mean values) ...	·274	55·425	·271	28·721

l=length, stem or full, in centimetres. w=weight in kilogrammes. k=a constant.

It is evident that the series of values for standing height and weight at the several ages are quite as uniform and regular as, or even more uniform than, those for stem length and weight. The mean values for the series of exponents for standing height and for sitting height are practically identical, being

0.274 and 0.271 respectively, while the constant for standing height is very approximately double that for sitting height. When the values of n and k are calculated for all the boys, weighting the observations but ignoring age, the values obtained are 0.310 and 0.315 for standing height and stem length respectively with constants 48.467 and 24.261, the latter almost exactly in the ratio of two to one. These constants are for weight in kilogrammes. For weight in grammes the corresponding constants are 5.6944 and 2.7536. The formula - $l = 2.7536\,w^{\cdot 315}$ - thus obtained, connecting stem length and weight, is very similar to that calculated by Professor Dreyer as suitable for all ages, namely, $l = 2.6298\,w^{\cdot 319}$

Vital capacity and height relationship shown by power formulae. Formulae of a similar type have been calculated from the data to show the relation of stem length and standing height respectively to vital capacity at each year of age and for the group of all ages above 11. The number at age 11 was small and the values obtained for the constants were somewhat different from those found for the later years, apparently indicating that the two measures of stature at this early age are not in the same or such close relationship to vital capacity as in the later years, although difficulty in manipulating the spirometer may be responsible in some degree for the discrepancy. The values are shown in comparison in Table X

TABLE X.

Manchester Grammar School Data.

Formula: V. C. $= kl^n$.

Age group	Vital capacity and standing height		Vital capacity and stem length	
	n_1	k_1	n_2	k_2
12 years	2·245	·031854	2·080	·29326
13 "	2·444	·012028	2·802	·013381
14 "	2·252	·03207	2·302	·11811
15 "	2·590	·005921	2·359	·093903
16 "	2·569	·006670	2·358	·095625
17 "	2·561	·007036	2·600	·032098
18 "	2·512	·010103	2·643	·0290900
All ages (weighted observations)	2·700	·003372	2·612	·030537
All ages (mean values)	2·431	·013453	2·417	·072853

V. C. in cubic centimetres. l in centimetres.

and appear to support the view that the standing height exhibits as constant and as regular a relationship to vital capacity at the different ages as the stem length and that there is no apparent advantage in using stem length in preference to full stature in the construction of formulae with the view of determining the normal vital capacity for a given height. The average values for the exponents in the formulae for boys at the several ages are 2.431 and 2.417, almost identical, while those for weighted observations, ignoring age, are 2.700 and 2.612 respectively.

Accuracy of prediction by regression and power formulae.

It seemed desirable to test and compare the accuracy of the predictions of the weight and vital capacity (respectively from the full length and stem length) deduced from the regression equations and from the power formulae; the latter are of the type suggested by Professor Dreyer as already described, but are calculated from the same data as the regression equations. For this purpose eight cards were taken at random from those of the groups of boys in each half year of age from 11.6 to 18.6, making in all 11.2, a fair sample. For this rough test it was necessary to use the data from which the constants were calculated as no other data covering the same age period were available at the time. In the first place theoretical weight values were obtained from the regression formula connecting stem length and weight and secondly from the power formula, determined for boys of all ages irrespective of the number at each age. The root-mean-square deviations of the observed from the predicted values were determined and were found to be 4.33 cm. and 5.00 cm. respectively, suggesting that the regression formula gives, if anything, the better fit (Table XI).

TABLE XI.

Manchester Grammar School Data. Test of Accuracy of Prediction of Weight and Vital Capacity by Different Formulae.

	By regression equation 1	By power formula 2
Weight from sitting height (112 observations) ...	$\Delta = 4{\cdot}33$ cm.	$\Delta = 5{\cdot}00$ cm.
Weight from standing height (112 observations) ...	$\Delta = 4{\cdot}57$ cm.	$\Delta = 4{\cdot}94$ cm.
Vital capacity from sitting height (104 observations)...	$\Delta = 452$ c.c.	$\Delta = 450$ c.c.
Vital capacity from standing height (104 observations)	$\Delta = 455$ c.c.	$\Delta = 446$ c.c.

where Δ = root-mean-square deviation.

Estimating the weight from the full stature by two similar formulae the root-mean-square deviations were 4.57 cm. and 4.94 cm. respectively. Comparison of these with the previous figures indicates that the accuracy in prediction of weight in the group of cases comprising in all about one-tenth of the total number of boys by a power formula of the type suggested by Professor Dreyer, when stem length is used, is practically identical with that obtained by using standing height. The fit for the weight obtained by means of the regression equation for stem length is apparently slightly better than that obtained from the equation for full stature, but the difference is really insignificant for practical purposes.

Vital capacity was then predicted from the stem length in the same sample but excluding those under 12 years (for the reason already given) by the regression equation and by the corresponding power formula. The correlation coefficient on which the regression equation was based was recalculated from the total boys excluding those under 11 years so that the two formulae, being derived from the same data, might be more truly comparable. The root-mean-square deviations from the original observations obtained by prediction with the two formulae - regression and power - were 452 c.c. and 450 c.c. respectively. The root-mean-square deviations, when vital capacity was predicted by the corresponding formulae for full stature, were 455 c.c and 446 c.c. respectively. It would thus appear that, in the data examined, the regression equation for stem length is not inferior to the corresponding power formula as an instrument of prediction. Although the full stature regression equation does not give quite so good a fit for vital capacity as that obtained by the corresponding power formula, the difference may be considered practically insignificant. It is evident, moreover, from Table XI that the accuracy of prediction of vital capacity, as of weight, obtained by the power formula and by the regression formula for full stature is at least equivalent to that obtained by the corresponding formulae for stem length.

From the data for the 100 adults of the police force, the 279 boys of Westminster School and the 215 boys of the L.C.C. School, power formulae of the type already described have also been calculated by the method of least squares. The formulae evaluated show for each individual group and also for all these groups associated together the relationship between (1) standing height and weight and stem length and weight, (2) standing height and vital capacity and stem length and vital capacity, and (3) weight and vital capacity (Table XII).

On comparing the formulae obtained for the Westminster boys with those for the Grammar School boys, it is found that the formulae for stem length and weight are in closer agreement than those for full length and weight, the exponent in the full length formula for the Westminster boys showing a slight decrease in value. In the combined group, however, it is found that the exponent in the stem length formula is as much in defect of that given in Professor Dreyer's formula as the exponent in the full stature formula is in excess of it.

On comparing the Westminster and Grammar School formulae for stem length and vital capacity and full stature and vital capacity it is found that the exponents in the former are

TABLE XII.

Showing Power Formulae Calculated for other Data.

	Standing height and weight $l_1 = kw^n$	Stem length and weight $l_2 = kw^n$	Standing height and vital capacity $\text{V. C.} = kl_1^n$	Stem length and vital capacity $\text{V. C.} = kl_2^n$	Weight and vital capacity $\text{V. C.} = kw^n$
100 adults	$l_1 = 105{\cdot}63w^{\cdot 124}$	$l_2 = 56{\cdot}973w^{\cdot 114}$	$\text{V. C.} = 9{\cdot}3618l^{1{\cdot}202}$	$\text{V. C.} = 27{\cdot}652l^{1{\cdot}138}$	$\text{V. C.} = 1803{\cdot}8w^{\cdot 229}$
279 boys of Westminster School. (Age 12–18)	$l_1 = 56{\cdot}744w^{\cdot 275}$	$l_2 = 24{\cdot}475w^{\cdot 315}$	$\text{V. C.} = {\cdot}00278l^{2{\cdot}749}$	$\text{V. C.} = {\cdot}028212l^{2{\cdot}650}$	$\text{V. C.} = 80{\cdot}709w^{\cdot 965}$
215 boys of L.C.C. School. (Age 5–13)	$l_1 = 35{\cdot}744w^{\cdot 395}$	$l_2 = 28{\cdot}003w^{\cdot 276}$	$\text{V. C.} = {\cdot}028443l^{2{\cdot}279}$	$\text{V. C.} = {\cdot}00473l^{3{\cdot}043}$	$\text{V. C.} = 261{\cdot}37w^{\cdot 606}$
Three groups taken together. (594 individuals)	$l_1 = 42{\cdot}219w^{\cdot 346}$	$l_2 = 26{\cdot}211w^{\cdot 297}$	$\text{V. C.} = {\cdot}003637l^{2{\cdot}700}$	$\text{V. C.} = {\cdot}0038061l^{3{\cdot}009}$	$\text{V. C.} = 95{\cdot}982w^{\cdot 917}$
Manchester Grammar School boys	$l_1 = 48{\cdot}467w^{\cdot 310}$	$l_2 = 24{\cdot}261w^{\cdot 315}$	$\text{V. C.} = {\cdot}003372l^{2{\cdot}700}$	$\text{V. C.} = {\cdot}030537l^{2{\cdot}612}$	$\text{V. C.} = 47{\cdot}481w^{1{\cdot}079}$

where l_1 = Full length in centimetres.
l_2 = Stem length in centimetres.
w = Weight in kilogrammes.
V. C. = Vital capacity in cubic centimetres.
k = a constant.

practically identical with those for the Grammar School. While the exponent of the full stature formula for the grouped observations remains more or less constant, the exponent of the corresponding stem length formula seems to show some degree of divergence from that evaluated for the Westminster data. Taking everything into consideration it would appear that the formulae for stem length are not more constant than those for full stature and cannot be regarded as in any way superior to the latter as instruments of prediction. In the power formula connecting vital capacity and weight derived from the Westminster data, the exponent is 0.97, while in that for the grouped observations it remains as high as 0.92.

As the corresponding exponent in the formula for the Grammar School data is practically unity there appears to be a significant divergence in all these data from what is given in Professor Dreyer's formula as the best value, namely 0.72.

DISCUSSION OF RESULTS AND CONCLUSIONS.

It now remains to discuss briefly the results that have been obtained and their bearing on the conclusions arrived at by others.

It would appear that, despite the definite tendency shown in recent work on the interrelationships of the physical measurements, to replace the full length by the stem length, the latter does not possess the many advantages over the former that have been frequently claimed or asserted. It would almost appear to be a matter of indifference as to which measurement of length is used.

In the data examined there is no evidence that the accuracy of prediction of vital capacity obtainable by a power formula of the type suggested is significantly greater than that obtained by the ordinary regression formula.

Professor Dreyer's formulae were originally deduced from observations on 16 individuals, men and boys ranging in age from 13 to 52 years, "who were carefully selected on account of their physical fitness and covered as widely different a range in weight, height, etc., as possible." Apart from the number of observations being so relatively small, that it is totally inadequate to form the basis of any general conclusion or to provide data for calculating a formula for general application, the process of selection adopted gives the formula so devised a wholly fictitious degree of accuracy as expressed in the tables by percentage error between calculated and observed values. The individuals chosen are more or less mean types lying in fairly close relationship to the best line drawn through the observations, and insufficient account is taken of the wide range of weights or of vital capacities found in individuals of, say, a similar height who are nevertheless normal and healthy. How great this variation may be, even in individuals at the same age and more especially for all ages taken together, has been shown by the magnitude of the standard deviation of the arrays of weights or vital capacities for height of a certain type found in the data for the boys examined. In these boys standard deviations of over 13 per cent. for the vital capacity array and over 9 per cent for the weight array have been found, and yet apparently there is no reason to describe them as abnormal. With a range of variation in the measurements so extensive as that described, it is difficult to fix the percentage deviations from the standards, - or values found by the formulae from the other measurements, - that may reasonably be considered to differentiate the normal from the abnormal with sufficient precision or within sufficiently narrow limits to be of practical use, for example, in the early diagnosis of disease. It seems very doubtful, indeed, if some of the percentage deviations that have been given for certain formulae are adequate, and further investigations would appear to be necessary before they can be accepted without considerable reservation.

As the observations for vital capacity can be fitted with fair approximation to the Gaussian curve of errors it may serve to emphasise the wide range of variation that exists in normal data like those examined if it is stated that roughly 30 per cent. of the observations lie outside the standard deviation. This can easily be ascertained by reference to the table of the probability integral.

THE WEST SCOTTISH SKULL AND ITS AFFINITIES.

by

Matthew Young M. D.

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<u>The West Scottish Skull and its Affinities.</u>

by

Matthew Young

A large collection of modern Scottish skulls comprising over 700 specimens is preserved in the Museum of the Anatomy Department of the University of Glasgow. These skulls were taken from a graveyard in Glasgow about 30 years ago. Unfortunately, no definite information can be obtained as to the period of time to which the skulls actually belong but it is probable that the majority may be referred to a date not later than the first half of the nineteenth century. The skulls were examined and measured in the year 1914 with the kind permission of Professor Bryce and a paper based on the results of the investigation entitled "A Contribution to the Study of the Scottish Skull" was published in the Transactions of the Royal Society of Edinburgh in 1916*. At the time this work was carried out, it did not seem essential for the purpose in view to attempt to sex the whole of the skulls and although a large series of measurements on all the skulls in the collection was made and published in tables in the paper referred to the analysis in the text was based on samples of approximately 405 of the more typical males and 100 of the more typical females respectively. A group of the skulls approximately 100 in number in which the sex characters were less well-defined was left as of doubtful sex although it was recognised that the great majority of these were probably female.

Since the paper was published it has become more fully realized that the mean values of the measurements of the characters given therein could not be strictly regarded as truly representative of the two sex groups in the collection, more especially of the females, when such a relatively large

* Trans. Roy. Soc. Edin. Vol LI, Part II. No. 9, 1916

number of the less determinate sex type was excluded from the averages. It was therefore thought to be advisable, if time and opportunity permitted, to resex the complete series and to recalculate the averages and variability of the cranial characters. Professor Bryce, at the request of the writer, very kindly consented to undertake the task of resexing the whole series including those that had previously been left as of doubtful sex. The number of skulls then available for analysis was 667 comprising 413 considered to be male and 254 considered to be female. The means and standard deviations of the measurements of the characters in these complete sex groups were recalculated. The constants for the group of male skulls were found to be practically identical with those already published. In the female group which now included the great majority of the skulls previously left provisionally as of doubtful sex as well as a number exceeding fifty which had been considered to be female but had not been used in the first analysis, the mean values of the absolute measurements of the characters showed in the majority of instances a slight increase. A comparison of the mean values and variability of the principal characters in the original sample of 100 female skulls and the larger group of 254 skulls from the resexed series is shown in Table 1. The mean increase in the glabello-occipital length (L), the basio-bregmatic height (H') and the zygomatic breadth (J) respectively is approximately 1.5 mm; in the maximum parietal breadth (B), the minimum frontal breadth (B'), the basi-alveolar length (GL), the nasi-alveolar height (GH) and the basi-nasal length (LB) about 1 mm; in the horizontal circumference (U), the transverse arc (Q) and the sagittal arc (S) from 3.0 to 3.5mm; in the intermalar breadth (GB), the nasal height (NH') and the palatal length (G_1) between 0.6 and 0.7mm and in the cubic capacity (C) 22 c.c. over the corresponding measurements in the smaller sample. As the differences in the mean values

TABLE 1.

Showing the comparison of the mean values and variability of the principal cranial characters in the sample of 100 female skulls and the larger growth of 254 skulls.

acter	Sample of 100 skulls Mean	SD	Group of 254 skulls Mean	S'D
ial capacity (C)	1314.50±6.31	93.51±4.46	1336.60±4.37	103.35±3.09
alic index(100 B/L)	76.03±0.19	2.89±0.14	76.05±0.12	2.84±0.09
ht index (100 H'/L)	70.31±0.20	3.00±0.14	70.66±0.12	2.76±0.08
dth-height index(100 B/H')	92.53±0.30	4.42±0.21	93.06±0.17	4.10±0.12
l index(100 NB/NH')	46.77±0.30	4.49±0.21	46.71±0.21	4.91±0.15
tal index (rt)(100 O2/O1)	88.53±0.35	5.21±0.25	88.38±0.22	5.10±0.15
tal index(100 G2/G1)	77.27±0.42	6.17±0.29	76.39±0.27	6.42±0.19
ello-occipital length(L)	177.97±0.32	4.75±0.23	179.45±0.22	5.26±0.16
mum breadth(B)	135.16±0.30	4.40±0.21	136.29±0.19	4.57±0.14
mum frontal breadth(B')	92.66±0.25	3.76±0.18	93.62±0.18	4.30±0.13
bregmatic height(H')	125.01±0.31	4.61±0.22	126.63±0.19	4.60±0.14
alveolar length(GL)	88.61±0.31	4.62±0.22	89.82±0.20	4.73±0.14
nasal length (LB)	93.82±0.21	3.11±0.15	94.89±0.16	3.68±0.11
alveolar length(G'H)	65.83±0.25	3.67±0.18	66.67±0.16	3.88±0.12
rzygomatic diameter(J)	118.16±0.27	3.94±0.19	119.63±0.17	3.93±0.12
rmalar diameter(GB)	85.09±0.25	3.64±0.17	85.80±0.16	3.82±0.11
yo-occipital circum.(U)	503.61±0.72	10.64±0.51	507.14±0.51	12.13±0.36
sverse arc (Q)	299.21±0.61	9.04±0.43	302.61±0.41	9.63±0.29
ttal arc (S)	363.15±0.69	10.16±0.48	366.43±0.49	11.53±0.34
l height (NH')	48.41±0.20	3.00±0.14	49.07±0.13	3.01±0.09
l width (NB)	22.56±0.12	1.71±0.08	22.63±0.08	2.01±0.06
tal height (O2)	32.95±0.14	2.07±0.10	32.91±0.08	1.96±0.06
tal width (O'1)	37.24±0.10	1.48±0.07	37.29±0.07	1.57±0.05
tal length (G 1)	47.01±0.20	2.96±0.14	47.61±0.13	3.12±0.09
tal breadth (G 2)	36.21±0.14	2.09±0.10	36.15±0.10	2.39±0.07

of these corresponding measurements in the two groups exceeds three times their probable errors they must be regarded as probably significant. The means of the remaining absolute measurements given in the table for the two groups are not significantly different.

The inclusion of the additional large group of female skulls has not changed materially the mean relative proportions of the skulls as shown by the indices. The cephalic index is identical in the two series and the slight differences shown in the remaining indices cannot be considered significant. Slight differences are shown in the variability of the several characters in the two groups but in none is the change of such a degree that any significance should be attached to it.

The collection of skulls is so large and important that it seemed most desirable that tables of the mean values and variability of the principal characters for the separate sexes which would be generally accepted as reliable and truly representative should be made readily available for comparison with other series of skulls. The 700 skulls preserved at the University of Glasgow do not comprise the whole of the original collection as approximately 300 skulls of the same series were not transferred to the University but were retained at St. Mungo's Medical School, Glasgow, and are still preserved there in the Anatomical Museum. Through the kindness of Professor Battersby, access to this section of the collection and permission to examine and measure the skulls was obtained. These skulls were first sexed provisionally by the writer but were later also resexed by Professor Bryce. In this part of the collection, excluding juvenile skulls and certain skulls in which the facial portion had been detached there were available for measurement 258 more or less complete adult skulls of which 137 were considered to be male and 121 female. The measurements in these skulls were made in accordance with the scheme devised by Professor Pearson and used in the Biometric School and the methods of measurement described in the memoirs published in Biometrika were carefully followed with one or two exceptions to which reference will be made later. This scheme of measurement had been generally but not closely followed in measuring the skulls at the University in 1914 and the majority of the skulls comprising this division of the collection were therefore remeasured to ensure that the figures would be comparable with the measurements taken in the series at St. Mungo's College and to verify some of the previous measurements. Since the skulls at the University were measured in 1914, a number of specimens has unfortunately been removed from the collection. Combining the two sections of the original collection preserved in the two museums, there were available for analysis 901 adult skulls of which 524 were considered to be male and 377 female. The mean values and standard deviations of the series of characters measured are based on these numbers or on such smaller numbers as it was possible in certain instances to make the measurements. These are shown in Table 2. As these values are based on all the adult skulls available, they may be accepted with some degree of confidence as being truly representative of the two sexes in this large collection of West Scottish skulls.

A brief reference may be made to the measurements which were not taken in strict accordance with the scheme devised and followed in the Biometric School.

1. The Cranial Capacity: The cubic capacity of the skulls at the University had been estimated in 1914 by filling with No. 8 lead shot. Although the desirability of reestimating the capacity by the method of tight packing with mustard seed and weighing the content, as described by Macdonnell* was fully appreciated, sufficient time was not available to carry out this procedure in the 258 skulls at St. Mungo's

* Biometrika Vol III. 1904 pp. 391-445

TABLE 2.

Showing the mean values and variability of the cranial characters.

Character	Males No. of Obs.	Males Means	Males S.D.	Males C. of V.	Females No. of Obs.	Females Means	Females S.D.	Females C. of V.
C	506	1460.47±3.71	123.80±2.63	8.48±0.18	364	1328.57±3.59	101.50±2.54	7.64±0.19
F	524	186.12±0.18	6.01±0.13	3.23±0.07	374	179.47±0.18	5.28±0.13	2.94±0.07
L	524	188.18±0.18	6.13±0.13	3.26±0.07	374	179.86±0.18	5.19±0.13	2.89±0.07
B	524	139.15±0.14	4.81±0.10	3.46±0.07	374	135.62±0.15	4.40±0.11	3.24±0.08
B'	425	96.64±0.15	4.42±0.10	4.57±0.11	374	93.38±0.15	4.16±0.10	4.45±0.11
H'	521	132.91±0.16	5.52±0.12	4.15±0.09	372	126.96±0.16	4.63±0.11	3.65±0.09
OH	522	111.76±0.13	4.45±0.09	3.98±0.08	373	107.31±0.13	3.80±0.09	3.54±0.09
LB	516	100.79±0.12	4.20±0.09	4.17±0.09	370	94.99±0.13	3.81±0.09	4.01±0.10
Q	420	306.43±0.35	10.68±0.25	3.49±0.08	368	296.62±0.32	9.16±0.23	3.09±0.08
Q'	420	309.64±0.36	10.94±0.25	3.53±0.08	368	300.19±0.33	9.39±0.23	3.13±0.08
S	522	378.51±0.38	13.02±0.27	3.44±0.07	376	365.67±0.41	11.73±0.29	3.21±0.08
S1	522	130.93±0.19	6.34±0.13	4.84±0.10	377	127.02±0.21	5.95±0.15	4.68±0.11
S2	522	127.36±0.23	7.79±0.16	6.12±0.13	377	122.51±0.24	6.91±0.17	5.64±0.14
S3	522	120.00±0.22	7.42±0.15	6.18±0.13	376	115.88±0.24	6.91±0.17	5.96±0.15
S'1	522	113.18±0.14	4.85±0.10	4.29±0.09	377	109.37±0.16	4.47±0.11	4.09±0.10
S'2	522	98.17±0.16	5.31±0.11	5.41±0.11	376	94.84±0.16	4.73±0.12	4.99±0.12
U	497	523.83±0.43	14.25±0.30	2.72±0.06	370	506.65±0.44	12.51±0.31	2.47±0.06
PH	340	20.84±0.11	2.91±0.08	13.96±0.36	255	19.94±0.11	2.55±0.08	12.79±0.38
G'H	423	72.17±0.15	4.53±0.11	6.28±0.15	279	68.15±0.16	4.07±0.12	5.97±0.17
GB	500	90.50±0.15	4.89±0.10	5.40±0.12	346	85.82±0.14	3.94±0.10	4.59±0.12
J	466	127.94±0.17	5.37±0.12	4.20±0.09	327	120.26±0.15	4.07±0.11	3.38±0.09
NH'	372	50.19±0.12	3.39±0.08	6.75±0.17	230	47.83±0.14	3.06±0.10	6.40±0.20
NHR	519	50.95±0.10	3.25±0.07	6.38±0.13	370	48.67±0.10	2.74±0.07	5.63±0.14
NHL	514	50.86±0.10	3.20±0.07	6.29±0.13	369	48.70±0.10	2.73±0.07	5.61±0.14
NB	523	23.31±0.05	1.78±0.04	7.64±0.16	372	22.47±0.07	1.89±0.05	8.41±0.21
O1R	501	41.37±0.05	1.71±0.04	4.13±0.09	354	39.75±0.06	1.60±0.04	4.03±0.10
O1L	494	41.39±0.05	1.70±0.04	4.11±0.09	353	39.82±0.06	1.62±0.04	4.07±0.10
O2R	500	53.55±0.06	2.09±0.04	6.23±0.13	354	33.28±0.07	1.93±0.05	5.80±0.15
O2L	494	33.64±0.06	2.07±0.04	6.15±0.13	353	33.42±0.07	1.95±0.05	5.83±0.15
O'1	472	39.64±0.05	1.70±0.04	4.29±0.09	337	37.98±0.06	1.56±0.04	4.11±0.11
G1	239	49.55±0.15	3.49±0.11	7.04±0.23	219	46.62±0.15	3.22±0.10	6.91±0.22
G'1	237	45.61±0.14	3.17±0.10	6.95±0.22	219	42.91±0.13	2.92±0.09	6.80±0.22
G2	239	37.80±0.13	2.99±0.09	7.91±0.24	219	36.27±0.12	2.72±0.09	7.50±0.24
GL	423	94.30±0.17	5.16±0.12	5.47±0.13	279	89.50±0.20	4.92±0.14	5.50±0.16
fml	421	35.75±0.08	2.43±0.06	6.80±0.16	368	34.41±0.08	2.15±0.05	6.25±0.16
fmb	421	30.15±0.07	2.23±0.05	7.40±0.17	368	28.89±0.07	2.05±0.05	7.03±0.17
100 B/L	524	74.00±0.08	2.62±0.05	3.54±0.07	374	75.49±0.10	2.81±0.07	3.72±0.09
100 B/F	524	74.79±0.08	2.58±0.05	3.45±0.07	374	75.64±0.10	2.76±0.07	3.65±0.09
100 H'/L	521	70.68±0.09	3.00±0.06	4.24±0.09	370	70.61±0.10	2.90±0.07	4.11±0.10
100 B/H'	521	104.88±0.14	4.84±0.10	4.61±0.10	372	107.04±0.17	4.74±0.12	4.43±0.11
100 G'H/GB	329	79.92±0.21	5.67±0.15	7.09±0.19	270	79.77±0.21	5.13±0.15	6.43±0.19
100 NB/NHR	421	46.14±0.14	4.17±0.10	9.04±0.21	370	46.21±0.15	4.17±0.10	9.02±0.22
100 NB/NHL	421	46.15±0.14	4.17±0.10	9.04±0.21	370	46.16±0.15	4.26±0.11	9.23±0.23
100 NB/NH'	372	46.85±0.16	4.61±0.11	9.84±0.24	230	47.06±0.22	4.84±0.15	10.28±0.32
100 O2/O1R	500	81.33±0.15	5.06±0.11	6.22±0.13	354	83.95±0.17	4.73±0.12	5.63±0.14
100 O2/O1L	494	81.49±0.15	4.94±0.11	6.06±0.13	353	84.14±0.17	4.86±0.12	5.78±0.15
100 O2/O'1R	466	84.83±0.16	5.27±0.12	6.21±0.14	331	87.71±0.17	4.69±0.12	5.35±0.14
100 fmb/fml	421	84.53±0.17	5.28±0.13	6.25±0.15	368	84.08±0.17	4.90±0.12	5.83±0.14
100 G2/G1	239	76.70±0.32	7.41±0.23	9.66±0.30	218	78.13±0.32	6.90±0.22	8.83±0.29
∠P	332	86.63±0.11	3.10±0.08	3.58±0.09	267	86.47±0.12	2.86±0.08	3.31±0.10
∠N	423	63.45±0.12	3.64±0.08	5.74±0.13	280	63.73±0.14	3.35±0.10	5.26±0.15
∠A	423	73.37±0.11	3.22±0.07	4.39±0.10	280	72.98±0.13	3.21±0.09	4.40±0.13
∠B	423	43.25±0.10	2.94±0.07	6.80±0.16	280	43.41±0.11	2.74±0.08	6.31±0.18
∠θ1	332	29.69±0.11	2.96±0.08	9.97±0.26	267	29.87±0.11	2.66±0.08	8.91±0.26
∠θ2	332	13.42±0.12	3.16±0.08	23.55±0.62	267	13.47±0.12	2.97±0.09	22.05±0.64
OcI	521	59.15±0.09	3.14±0.07	5.31±0.11	372	58.89±0.08	2.24±0.06	3.80 0.09

Medical School and the 700 skulls at the University. The capacities of the skulls at St. Mungo's were therefore estimated with shot as the others had been and the mean values which are tabulated have been calculated from the cubic content estimated in this manner. It is probable, however, that the mean capacities for the two sexes do not deviate very appreciably from those that would have been found by the more accurate and scientific method, as, on using Miss Hooke's formulae* for estimating the cubic capacity (C), from the mean linear dimensions (1) L.B. and H′ and (2) L, B. and OH, in London skulls the results are as follows:

For the male, $C = .000366\ LBH' + 198.87 \pm \frac{45.8}{\sqrt{n}}$

gives 1473.2 ± 2.0 c.c.

and $C = .000416\ LB\ (OH) + 247.86 \pm \frac{44.3}{\sqrt{n}}$

gives 1466.3 ± 2.0 c.c.

in place of the tabulated value 1460.5 ± 3.7 c.c.

For the female, $C = .000366\ LBH' + 199.43 \pm \frac{38.9}{\sqrt{n}}$

gives 1333.3 ± 2.0 c.c.

and $C = .000422\ LB\ (OH) + 210.83 \pm \frac{41.8}{\sqrt{n}}$

gives 1315.4 ± 2.2 c.c.

in place of the tabulated value 1328.6 ± 3.6 c.c.

2. Omission of some characters: Certain measurements, namely, the glabellar projective length (L′), the vertical height (H), and others relating to the nose and orbit, usually represented by the symbols DS, DC, DA, SS, SC and EOW, have been omitted.

3. Cranial contours: The importance of tracing outlines of random samples of 100 skulls from the male and female groups respectively in the three standard planes for the purpose of constructing mean cranial contours was recognised but time for the procedure to be carried out was not available.

It may be stated here that in measuring the orbital width the nasal margin of the orbit was determined by Fawcett's circular method†, and that the auricular height having been determined

* Biometrika, Vol XVIII 1926 pp.33 and 34.

† Biometrika Vol I p. 430
Vol VIII pp 311-312.

by Ranke's craniophore,the readings were adjusted by deducting 2.5 mm to allow for the error in the instrumental record which was first discovered and described by Miss Tildesley.

Reference to Table 2 shows that the variability for skull length in the male is 6.1 mm and for skull breadth 4.8 mm. As these values lie between 6.5 and 5.5 and 6.5 and 3.3 respectively, the conclusion may be drawn in accordance with Professor Pearson's criterion* that the group of male skulls is neither heterogeneous nor a rather stringently selected sample. In the female group, the standard deviation for skull length is 5.2 mm and for skull breadth 4.4 mm which seem to indicate that the female sample may also be considered homogeneous and not stringently selected.

It is well known that the accurate sexing of a certain proportion of any long series of skulls presents some difficulty as the sexual characters are not always well-defined. The sexual dimensional differences in the Scottish group seem to be in fairly close agreement with those shown in some other long series of skulls,namely,the 17th century Londoners from Whitechapel and Farringdon Street. This concordance is illustrated in regard to several of the principal measurements in Table 3.

Having determined the means and variability of the principal characters of the relatively long West Scottish series, it seemed to be of interest to compare the group with certain other groups of British skulls for which similar measurements were available by means of the coefficient of racial likeness, a method of comparison of racial types which was devised a few years ago by Professor Pearson *–* . The series of skulls selected for comparison with the West Scottish group were the Lowland Scottish,† the British Iron Age, the British Neolithic , the

† This group was obtained by Dr Morant by pooling the Scottish skulls described by Sir Wm Turner that were mainly derived from the region to the south of the River Forth.

* Biometrika. Vol II (1903) Craniological Notes.

– Biometrika Vol XVI (1924) (pp 11-14)
Biometrika Vol XVIII (1926) p.105

TABLE 3.

Showing the differences in mm. between the male and female mean values for certain characters in the Scottish series in comparison with those shown in the 17th century Londoners.

Character.	West Scottish series.	Whitechapel series.	Farringdon Street series.
L	8.3	8.7	7.2
F	6.6	7.3	6.1
B	3.6	6.0	6.7
B'	3.2	4.9	3.5
H'	5.9	7.4	7.2
OH	4.5	5.4	4.8
U	17.1	20.5	22.2
S	12.8	14.3	16.5

Anglo-Saxon and the Whitechapel and Farringdon Street collections of 17th century Londoners. The comparable data for these groups have all been obtained from the memoirs in Biometrika*.

The coefficients of racial likeness were calculated, using the mean values of the 31 characters, 12 indices and angles and 19 absolute measurements, selected and used by Morant as being most suitable for the purpose or as many of these characters as were available for the different series, excluding all means based on less than 5 skulls. In calculating the values of α for the several characters the standard deviations used were those derived from the longest series of skulls available, namely, the Egyptian series of the XXVI-XXX dynasties**, as these have been used in practically all the comparisons that have been made in the memoirs in Biometrika, and it seemed desirable to adhere closely to the methods described there for the sake of uniformity.

The coefficients of racial likeness between the West Scottish series of males and females and the several groups with which they have been compared are shown in Tables 4 and 5 and the values of $\alpha = \frac{n_s n'_s}{n_s + n'_s}\left(\frac{M_s - M'_s}{\sigma_s}\right)^2$ for the different characters in the Scottish and the other series of skulls in the two sexes are shown in Table 6.

Coefficients of Racial Likeness.

In the male groups, the mean number of skulls available for measurement of the characters used in calculating the coefficients of racial likeness vary from 30 to 90 but the numbers are approximately equal in the respective pairs of series, Lowland Scottish and British Iron Age, Anglo-Saxon and British Neolithic and Whitechapel and Farringdon Street 17th century Londoners. It is thus possible to compare directly the relative degree of association of the West Scottish group with the members of each of these series of pairs. The coefficients

* Mainly from Biometrika Vol XVIII, 1926, pp 83 and 84

** Biometrika Vol XVI p. 328 (1923-24)

TABLE 5

Coefficients of racial likeness.

Western Scottish females
(337.7)*

$\bar{n}_1 = \bar{n}_2 = 75; \quad \frac{\bar{n}_1 \times \bar{n}_2}{\bar{n}_1 + \bar{n}_2} = 37.5$

		All characters.	Indices & angles.	All characters.	Indices & angles.
wland Scottish	(24.0)*	2.74±.20 [23]*	4.58±.36 [7]*	4.59±.20 [23]*	7.67±.36 [7]*
itish Iron Age	(27.1)	3.95±.22 [19]	3.35±.39 [6]	5.90±.22 [19]	5.01±.39 [6]
glo-saxon	(29.4)	12.87±.17 [31]	16.29±.28 [12]	17.85±.17 [31]	22.59±.28 [12]
itish Neolithic	(16.6)	16.35±.25 [14]	11.53±.55 [3]	38.75±.25 [14]	27.33±.55 [3]
itechapel	(88.7)	6.32±.18 [27]	6.41±.30 [10]	3.37±.18 [27]	3.42±.30 [10]
rringdon Street	(110.2)	13.91±.17 [31]	22.48±.28 [12]	6.28±.17 [31]	10.15±.28 [12]

degree of divergence of the several series from the West Scottish. The C.R.L.s, adjusted to correct for the varying number of male skulls in the groups, are also shown in Table 4. They indicate that, of the six groups which are compared with the West Scottish, the British Iron Age type diverges least from it, while the Lowland Scottish and Whitechapel Londoners are slightly more divergent from it but diverge to an equal degree. The divergence of the remaining types from the West Scottish increases in the following sequence: Farringdon Street 17th century Londoners, Anglo-Saxon and British Neolithic. With respect to skull shape, however, as shown by the adjusted coefficients for indices and angles, the Anglo-Saxon and Neolithic seem to be relatively less divergent from the West Scottish type than the Farringdon Street 17th century Londoners.

The coefficients of racial likeness for the females shown in Table 5 indicate that the British Iron Age type and the Lowland Scottish type are "closely" associated, the Whitechapel 17th century Londoners "moderately" associated and the Anglo-Saxons "doubtfully" associated with the West Scottish type whereas the Farringdon 17th century Londoners and the British Neolithic are to a slight degree divergent from it. The coefficients adjusted to make allowance for the varying number of skulls in the several groups (Table 5) suggest that the Whitechapel 17th century Londoners are relatively least divergent from the West Scottish type and that the divergence increases progressively in the groups Lowland Scottish, British Iron Age, Farringdon Street Londoners, Anglo-Saxon and British Neolithic. In regard to shape characters alone, the same sequence of relative divergence holds except that the British Iron Age type shows less deviation than the Lowland Scottish from the West Scottish type.

Comparison of Mean Measurements

The values of $\alpha = \frac{n_s n'_s}{n_s + n'_s}\left(\frac{M_s - M'_s}{\sigma_s}\right)^2$ between the series of pairs of corresponding characters which were used in computing the C.R.L.s between the West Scottish and the several racial

TABLE 6.

Showing the values of $\alpha_c \dfrac{n_s n'_s}{n_s + n'_s}\left(\dfrac{M_s - M'_s}{\sigma_s}\right)^2$

Character.	Lowland Scottish. ♂	Lowland Scottish. ♀	British Iron Age. ♂	British Iron Age. ♀	British Neolithic. ♂	British Neolithic. ♀	Anglo-saxon. ♂	Anglo-saxon. ♀	Whitechapel. ♂	Whitechapel. ♀	Farringdon Street. ♂	Farringdon Street. ♀
100 B/L	11.52	8.95	14.89	0.28	35.43	4.31	3.22	8.30	1.31	9.45	28.73	8.58
100 H'/L	0.22	0.28	0.25	0.10	1.35	8.76	0.69	2.51	5.53	24.59	48.03	97.97
100 B/H'	5.76	3.89	7.13	1.12	7.43	24.53	0	3.84	15.42	6.78	124.16	86.86
100 G'H/GB	-	-	-	-	13.56	-	32.68	105.17	21.42	8.09	17.55	36.99
100NB/NHR	-	-	-	-	0.25	-	4.99	30.74	9.27	9.81	9.10	35.19
100NB/NH'	15.52	14.13	0.04	7.04	-	-	-	-	-	-	-	-
100 O2/O1R	-	-	-	-	-	-	8.29	19.87	30.43	5.64	0.24	0.12
100 O2/O1'R	10.66	2.39	0.39	-	6.93	-	-	-	-	-	-	-
100fmb/fml	-	-	-	-	0.13	-	2.49	3.13	0	-	3.06	0
100 G2/G1	-	-	-	-	-	-	8.37	1.05	17.21*	0.15	3.68	2.34
Occ. Ind.	-	-	-	-	-	-	3.01	1.84	-	-	13.87	0.48
∠P	-	-	-	-	-	-	3.27	14.44	1.26	1.79	2.54	4.37
∠N	2.04	6.07	11.26	17.32	0.69	-	2.76	16.43	15.67	4.46	2.47	3.76
∠A	0.03	3.32	0.02	0.23	2.18	-	5.68	0.19	0	3.30	0.05	5.15
C	3.33	0.22	3.16	0.04	9.76	94.64	15.52	5.27	1.31	6.38	2.52	11.80
L	0.54	0.11	1.07	0.04	44.54	7.12	9.21	9.50	2.68	1.14	1.21	15.87
B	18.16	8.61	18.22	0.94	0.41	0.02	23.73	0	10.65	4.03	50.17	0.06
B'	0.46	1.16	4.87	11.96	10.07	0.48	1.55	2.82	12.06	0.66	0.27	0.09
BH	-	-	-	-	15.62	-	9.33	13.91	0.57	2.78	12.67	19.25
H'	0.91	0.12	0	0.49	-	34.07	-	-	-	-	-	-
LB	3.47	0.07	1.95	1.23	8.01	4.88	20.19	11.30	3.95	0.66	2.97	5.60
Q	0.05	0.81	0.80	-	2.49	-	9.41	0.56	2.14	8.14	0.24	36.55
S	0.19	1.43	0.15	1.21	20.60	10.77	0.62	0.20	1.31	7.36	0.06	12.14
U	6.22	1.14	6.81	3.48	75.57	38.18	22.53	6.31	0.13	5.63	20.36	1.19
G'H	1.02	0.05	15.63	24.23	3.38	-	0.30	9.27	14.80	17.36	11.55	23.55
J	24.45	5.20	17.18	14.27	11.27	12.25	44.27	35.26	9.11	0	18.10	0.02
NHR	-	-	-	-	0.15	2.36	4.18	0.36	0.73	0	7.00	3.62
NH'	19.21	25.21	1.47	0.04	-	-	-	-	-	-	-	-
NB	0.52	0.73	3.03	9.69	0.92	0.55	12.22	24.25	19.71	9.96	38.59	24.50
O1 R	-	-	-	-	-	-	14.76	32.04	55.75	36.61	20.25	9.17
O1'R	1.41	0.37	0.65	-	0.30	-	-	-	-	-	-	-
O2 R	5.87	0.60	0	0.32	7.03	-	0	1.86	0.67	2.55	9.54	3.01
G1	-	-	-	-	-	-	0.60	29.63	6.94	11.63	0.19	0.23
G2	-	-	-	-	5.67	-	42.98	35.39	13.20†	8.68	14.09	8.85
fml	0.07	1.26	0	-	0.67	-	9.04	4.55	0.15	-	14.82	3.69
fmb	-	-	-	-	0.06	-	3.03	0	0.20	-	2.93	1.08

* $\alpha = 0.17$ using Macdonnell's averages, the values in the tables are derived from Morant's averages
† $\alpha = 7.47$ for smaller numbers in which the points of measurement were well-defined.

types are shown in Table 6. From the magnitude of these values it can be readily seen in which characters the two racial types compared are most alike and in which they differ most significantly. As is customary, if α is between 0 and 2.7 the conclusion may be drawn that the characters have a common origin, if between 2.7 and 6.1 they are regarded as exhibiting differences which are probably significant, if above 6.1 the probability of their representing samples from the same population is exceedingly small.

Turning to the table, it is seen that in comparing the males in the West Scottish and Lowland Scottish groups, out of the 23 characters available there are seven in which α exceeds 6.1. These are B, J, NH′, U, 100B / L, 100 O_2 / O′, R and 100 NB / NH′. The mean maximum cranial breadth is smaller in the West Scottish than in the Lowland Scottish type but the maximum lengths and basio-bregmatic heights do not differ appreciably; the face is also narrower, the orbit shallower and the nasal aperture lower in the West Scottish type. The difference in the last measurement may, however, be partly accounted for by difference in technique of measurement as the base of the anterior nasal spine is not always a well-defined point. In comparing the females in the same two groups there are four characters in which α exceeds 6.1. These are B, NH, 100 B / L and 100 NB / NH. As in the males, the maximum biparietal diameter is distinctly less in the West Scottish than in the Lowland Scottish and the maximum cranial lengths and basio-bregmatic heights again correspond closely in the two groups. The face in the West Scottish female is narrower than in the Lowland Scottish type to a degree which is probably significant. The nasal aperture appears to be, as in the male, definitely lower in the former group.

On comparing the males of the West Scottish and Iron Age types, there are again, out of 23 characters available, seven in which α exceeds 6.1. As in the comparison with the Lowland Scottish male, three of the most outstanding differences occur in

B, J, and 100 B/L. The cranium is narrower in the West Scottibh type but the basio-bregmatic heights coincide and the maximum lengths are not significantly different; the face is also sensibly narrower in the West Scottish type than in the Iron Age type. The West Scottish female type differs from the Iron Age female type chiefly in the facial region; the calvarial lengths, breadths and heights do not differ significantly in the two groups. In the West Scottish type, however, the forehead is definitely narrower, the face narrower and longer, the nasal aperture narrower and the nas(i)al angle (N) smaller.

The West Scottish males differ from the Neolithic males principally in their less extensive cranial length and cranial height, the maximum breadths are in fairly close agreement. α is greater than 6.1 in 13 out of the 27 characters compared in the two types. Amongst these, in addition to cranial length and height already referred to are 100 B/L, B$'$, LB, U, S, C and J. The Scottish type has a narrower forehead, a shorter basi-nasal length, a smaller sagittal arc and horizontal circumference, and a smaller cubic capacity. The face and palate are also narrower and the orbit deeper in the Scottish male.

For comparison of the West Scottish female with the Neolithic only 14 characters are available after exclusion of these averages which are based on fewer than 5 skulls in the latter group. The averages used are in a number of instances derived from skulls less than 10 in number. Not too much emphasis should thus be laid on what appear to be notable differences in the females of the two types although their probable reality is supported by the fact that the important differences coincide largely with those found in the comparison of the males. In the West Scottish female the cranial vault seems to be shorter and distinctly lower than in the Neolithic but the maximum breadth corresponds closely in the two types. The West Scottish female also shows a smaller cubic capacity, a shorter sagittal arc and horizontal circumference and a narrower face than the Neolithic.

On comparing the West Scottish and Anglo-Saxon male groups, practically half the characters used show values of α exceeding 6.1 and 23 out of the 31 selected exceed 2.7. The outstanding difference in the two types is the smaller general average size of the West Scottish. This is shown by a significantly smaller calvarial length, breadth and height, a smaller basi-nasal length, transverse arc, horizontal circumference and cubic capacity. There are also notable differences in the face and palate in the two groups. The West Scottish face is decidedly narrower in both facial measurements, J and GB, and the orbital and nasal apertures and palate are also significantly less in width than in the Anglo-Saxon.

In the West Scottish and Anglo-Saxon female groups, the mean maximum cranial breadths are identical but the differences found in the females of the two types correspond generally with those found in the males. Thus the West Scottish female has a shorter and lower calvarium than the Anglo-Saxon female. It shows also a shorter basi-nasal length, a less extensive horizontal circumferenc and a cubic capacity which is smaller to a degree that is probably significant. In the West Scottish female, the face is distinctly narrower and longer, the orbital and nasal apertures narrower on the average, the palate shorter and narrower and the nasial angle smaller than in the female Anglo-Saxon.

The most striking differences in the calvaria of the males of the West Scottish series and the 17th century Londoners from Whitechapel are the less extensive maximum and frontal breadths in the former type. The maximum cranial lengths and auricular heights do not differ significantly in the two groups. There are also significant differences in the facial region of the skull. The West Scottish type has a narrower and a longer face, narrower orbital and nasal apertures and a relatively narrower palate. The nasial angle (N) is also significantly smaller. On comparing the females in the same two groups, α exceeds 6.1 in 13 of the 23 characters used. The maximum cranial breadth in the West Scottish exceeds that in the Londoners to a degree which is probably significant, the auricular height is also greater but the difference can hardly be considered significant, the basio-bregmatic height, the transverse and sagittal arcs are definitely greater than in the Londoners but the maximum cranial lengths do not differ sensibly. The values of α for 100B/L, 100H/L, 100B/H and C all exceed 6.1. As in the male, the West Scottish female has a longer face and narrower orbital and nasal apertures. The palate is longer and wider in the Scottish though the palatal index corresponds closely in the two types.

From the 17th century male Londoners found in Farringdon Street, the West Scottish type is chiefly distinguished by a narrower and higher calvarium; the skull length is not significantly different in the two types. Significant differences are also observed in the facial portion of the skull. As has been shown in comparison with the Whitechapel group, the West Scottish skull is longer and narrower in this region and the nasal and orbital apertures and palate are also narrower. The nasal opening is also lower and the orbit shallower in the West Scottish than in the Farringdon Street group.

The West Scottish female has a definitely shorter and higher skull on the average than the females from Farringdon Street though the maximum cranial and frontal breadths correspond closely in the two types. 100 H/L and 100 B/H thus show high values (between 80 and 100) and 100 B/L a value exceeding 6.1. The cubic capacity and the transverse and sagittal arcs are decidedly greater in the Scottish type than in the Londoners. In the facial region, the females of the two types show a somewhat similar divergence to that observed in the males. The West Scottish type has a definitely longer face and narrower nasal and orbital apertures and palate than the Farringdon Street type.

Conclusions

1. The West Scottish male skull resembles the British Iron Age type more closely than any of the other British types with which it has been compared including Morant's Lowland Scottish group.

2. The relative degree of divergence between the West Scottish and the 17th century Londoners from Whitechapel is identical with that shown between the West Scottish and the Lowland Scottish types.

3. The 17th century Londoners from Farringdon Street are distinctly less closely related to the West Scottish than are the Londoners of the same period from Whitechapel.

4. The relative degree of divergence of the West Scottish from the Anglo-Saxon and the Neolithic types is notably greater than that from the Farringdon Street Londoners.

5. In the female groups the order of relative divergence from the West Scottish does not accord exactly with that shown in the males. The Whitechapel females resemble the West Scottish most closely and the Lowland Scottish and Iron Age types are rather more divergent from it; the remaining groups follow the sequence shown in the male.

6. The close affinity between the modern West Scottish type, as illustrated by the collection in Glasgow, and the British Iron Age type, as described by Morant, lends support, so far as regards this group at least, to Morant's conclusion that the modern population of the greater part of Scotland is directly descended from the Iron Age type which has not been essentially modified since its first appearance.

7. The relatively close relationship shown to exist between the West Scottish type from Glasgow and the 17th century Londoners from Whitechapel is of great interest. During the survey of the Scottish skulls it was noted that a considerable proportion of them had the low retreating forehead and the comparatively low cranial vault which have been described as prominent features of these Londoners.